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SUMMARY

The Bay Area ATIS (Advanced Traveler Information System) Testbed is a public/private partnership aimed at enabling wide-spread dissemination of real-time information on transportation conditions and travel options. A fundamental premise of the testbed is that a public surveillance and database system, designed to open-architecture standards, will be the most effective stimulus for private sector innovations in ATIS technologies and, ultimately, their deployment.

When complete, the testbed infrastructure will include:

1) State-of-the-art surveillance systems, including probe vehicles, loop detectors and video-image-processing.
2) Public databases designed to open architecture standards enabling third-party delivery of traveler information.
3) Models for real-time prediction of future travel conditions.
4) Systems for communicating to travelers during pre-trip and enroute stages.

The database will contain up-to-the minute information on all available travel options, including automobile, bus and rail. The system will also eventually contain specialized information for commercial vehicles, such as waiting times at ocean terminals.

The testbed is designed to take full advantage of the private sector and public sector partnerships. The State of California will be chiefly responsible for the development and operation of the databases and surveillance systems. The private sector will have major responsibility for the development and deployment of technologies for information delivery. The university based PATH program will be responsible for research, testing and evaluation on information technologies.

By establishing this partnership, the testbed is expected to catalyze the growth of an ATIS industry, and to overcome the institutional barriers that have slowed the diffusion of ATIS technologies. The testbed will also allow for the development and testing of ATIS standards, which can eventually be used throughout the country.

This document presents the plan and procedures for conducting research within the Testbed. Background material on transportation in the Bay Area is provided, along with plans for development of the infrastructure and design of field operational tests. The report discusses the testbed's comprehensive research program, which encompasses assessment of ATIS technologies, to be intertwined with field operational tests. The report concludes with a testbed management plan, which includes rules and procedures to facilitate adherence to scientific procedure in the testbed operation.

ACKNOWLEDGEMENT

We have received valuable input from several individuals at the University of California. Among them are Professor Adib Kanafani, Professor Adolf May, PATH Director, Donald Orne, and Dr. Steven Shladover. In addition, Caltrans staff has been instrumental in the formation of some concepts in this plan. Particularly, Robert Ratcliff, Ann Hansen, and Jim Spinello provided useful insights.

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CHAPTER 1

INTRODUCTION

Several factors have motivated the development of Intelligent Vehicle Highway Systems (IVHS); among them are growing traffic congestion, concern for environmental degradation, the need to improve safety, and the desire to best utilize existing transportation infrastructure. Within the framework of IVHS, Advanced Traveler Information Systems (ATIS) will provide historical, real-time and predictive information to support travel decisions. ATIS offers significant benefits in terms of improving the travel experience of individuals and enhancing system performance. In the long-term, ATIS may reduce congestion and pollution, improve safety and increase mobility. However, the true potential of these systems has not been evaluated. To do this, an ATIS testbed in the Bay Area is proposed.

ATIS will provide improved information and increased awareness of travel options available to individuals; this may in turn influence the travel choices of individuals and consequently the network conditions. For example, by providing better transit and rideshare information, transportation managers may increase the likelihood of their use. The Bay Area ATIS testbed will provide a framework for field testing and evaluation of both automobile and transit-related ATIS technologies. The purpose of this report is to develop an initial framework for the evaluation of ATIS technologies and propose a research and management plan for the ATIS testbed.

PROBLEM DESCRIPTION

There is a need for organizational, conceptual and methodological frameworks which will allow the evaluation of ATIS technologies in a real-life context and encourage the integration of both automobile and transit related ATIS technologies. Such frameworks are needed in order to realize the true potential of ATIS.

Presently, there is no management plan for combining field operational tests (FOTs) of automobile and transit-related technologies. There is a need to conduct automobile and transit related experiments in parallel and integrate the results for developing effective information systems. Further, a clear conceptual and methodological framework is needed for evaluating ATIS technologies because our understanding of traveler behavior and system performance is not sufficient. For example, behavioral choice models assume perfect information; that is, individuals have knowledge of all alternatives. Clearly, such an assumption cannot be supported when evaluating the effect of information. Similarly, the effect of implementing various information dissemination strategies, such as system optimal or user optimal, have not been evaluated. In addition, it is necessary to combine behavioral and network models while accounting for the effect of information.

The research issues which will be addressed within the context of the testbed are:

- How can we design effective Advanced Traveler Information Systems?
- How will ATIS impact individuals' travel choices and system performance?

To summarize, within the framework of an ATIS testbed, researchers, practitioners, and technology developers will be able to cooperate and coordinate in conducting real-life experiments which test the feasibility of ATIS technologies, assess traveler response to ATIS, and evaluate the effects of ATIS on network performance. This will be done through various demonstration projects that will fit within the framework of a real-life ATIS testbed.

MOTIVATION

The Congested Corridors program of the Federal Highway Administration (FHWA) stipulates testing various concepts related to ATIS. In addition, the California State Assembly Bill

1239 identified the San Francisco Bay Area as one of four regions in California to be included in a feasibility study of automated traffic management and ATIS designed to alleviate traffic congestion problems.

For the past six years, Bay Area residents have prioritized traffic congestion problems as their number one concern (Bay Area Monitor 1991). Furthermore, within the next decade, vehicle miles of travel in the Bay Area are expected to increase by 53%, to 16.5 billion miles (MTC 1990). Many corridors in the Bay Area are severely congested and have a high frequency of incidents. However, it is unlikely that additional freeways will be built in the Bay Area due to environmental objections and lack of space. In lieu of additional freeway and road construction, redistribution of traffic on the existing system is being considered. One idea to address present and future traffic problems in the Bay Area is the use of ATIS technologies.

In 1991, Caltrans and the Institute of Transportation Studies (ITS) at the University of California at Berkeley, entered into an agreement that ITS would assist District 4 in conducting ATIS demonstration projects in the Bay Area. The ATIS testbed plan is motivated by the interest of public officials, private enterprises, and academics in determining the practical applicability and feasibility of advanced sensor and communication technologies for relieving traffic congestion and improving mobility in the Bay Area.

DEVELOPMENTS IN ATIS

Several major research efforts in ATIS are currently underway around the world. Other studies are in the proposal or early implementation stages. The systems being developed can be categorized as data collection, data processing and information dissemination. Although the Bay Area ATIS testbed will address the data collection and processing aspects, a relatively larger ***research effort*** will be devoted to the evaluation of data dissemination technologies.

Ideally, research and development efforts regarding information dissemination technologies should encourage testing systems that will support all travel choices (mode, destination, departure time, route, enroute diversion/return, parking and trip chaining) with ***static*** and ***dynamic*** information. However, none of the existing evaluation studies seem to propose a framework which allow systematic testing and eventual integration of systems which can support all travel choices. Typically, the ATIS testbeds limit themselves to a few technologies which only support a subset of travel choices. For example, the ADVANCE project in Chicago will test Motorola's information system technology which supports enroute diversion/return decisions and destination choices; similarly, the LISB experiment in Berlin is testing Siemens technology which supports enroute diversion/return and destination decisions.

Major U.S. Projects in ATIS

A number of operational tests of ATIS technologies are currently underway, funded from various public and private sources. The most notable U.S. projects are ADVANCE in Chicago, Illinois; TRAVTEK in Orlando, Florida; and PATHFINDER/SMART CORRIDOR in Los Angeles, California. These selected projects are discussed below.

ADVANCE

The ADVANCE project is one of the largest in the U.S. for testing the "Advanced Driver and Vehicle Advisory Navigation System" (ADVANCE 1990). Participants include Motorola, Inc., the Illinois Department of Transportation, the Federal Highway Administration, and the Illinois Universities Transportation Research Consortium. The project will test a route guidance system developed by Motorola with GPS (Global Positioning System) links to the radio frequency communication technology. Real-time traffic information will be transmitted to 4,500-5,000 vehicles equipped with navigation and information systems within a 250-square-mile suburban area northwest of Chicago. The number of participating vehicles is less than 1% of the vehicles in the region. However, this number should still be sufficient to gauge traffic conditions on at least 40% of the links in the area at five-minute intervals on weekdays.

TRA VTEK

The goal of the TravTek project is to test a route guidance system (see ***Vehicle Navigation and Information System [VNIS] Conference Proceedings*** 1991). Seventy five of the one hundred GM test vehicles (1992 model Oldsmobile Trofeos) will be assigned to specially recruited AAA members through Avis rentals. The remaining 25 automobiles will be tested with local drivers who travel frequently. Real-time traffic information from the specially equipped TravTek vehicles will be transmitted to and received by the traffic management center. Traffic information will be gathered by and processed at the traffic center and then transmitted to the TravTek vehicles via two-way radios. The surveillance system to be used for this project is on an 11 mile segment of I-4 which is equipped with video cameras, loop detectors and variable message signs installed and operated by the Florida Department of Transportation.

PATHFINDER/WART CORRIDOR

The Pathfinder--an ATIS experiment--preceded the current Smart Corridor activities in Los Angeles. The Smart Corridor project will evaluate traffic surveillance and control technologies, incident management procedures, methods for minimizing delays through better coordination, and opportunities for improved motorist information (JHK & Associates 1990). The Santa Monica Smart Corridor Project, California's first demonstration project in integrated ATMS/ATIS, focuses on the concept of integrated freeway and arterial traffic operations along with testing of technology options and development of related traffic models.

California ATMS Testbed Project

Presently, the Institute of Transportation Studies at the University of California, Irvine, in coordination with Caltrans District 12, is undertaking a multi-year, multi-disciplinary testbed project for advanced traffic management systems in the Southern California region. The study area encompasses two contiguous subareas within Orange County where major traveler decisions concerning freeway choice are made. The ATMS testbed project aims at developing an integrated

Transportation Operations System (TOS) based on real-time, computer-assisted traffic management and communication.

ATIS Lab at the University of California at Davis

The project currently underway at UC Davis is a multi-disciplinary research effort to study traveler response to ATIS. An Urban Travel Demand Simulation Lab will allow researchers to observe and closely analyze mode selection (drive alone, carpool/vanpool, transit) and route choice behavior. The lab will replicate a realistic urban travel environment with advanced two-way communication systems. From these experiments it will be possible to learn how people will adapt to ATIS and devise rules for travel planning.

ATIS Evaluation at the University of California at Berkeley

A precursor study of the Bay Area ATIS testbed is presently underway at UC Berkeley (Al-Deek, Khattak, and Kanafani 1992). This study will focus on designing a taxonomy of ATIS technologies, developing simulation tools for analysis of highway bottleneck performance under various ATIS information dissemination strategies, and studying traveler response to ATIS technologies through survey research. To evaluate the effect of traveler behavior on system performance, the results of behavioral models will be used in the simulation of bottleneck performance.

CONTEXT AND UNIQUE FEATURES OF THE BAY AREA TESTBED

The Bay Area offers a conducive environment to conduct a comprehensive study of ATIS technologies because:

- The Bay Area has unique geography that makes it an interesting site for testing automobile-related ATIS technologies.
- The transportation system in the Bay Area is relatively advanced and offers opportunities for

multimodal experiments due to the existence of BART, park-and-ride facilities, Mum, AC Transit, and ferries (in addition to the private automobile).

- The deployment of Automatic Vehicle Identification (AVI) technologies in the Bay Area will allow thousands of vehicles to serve as probes for the collection of travel information. The AVI tags are being installed to facilitate the movement of vehicles on toll bridges.
- Opportunities exist to validate network data from probe vehicles with the more conventional loop detectors to be installed in the Cornerstone project. In addition, a Freeway Service Patrol (FSP) system will be implemented in several sites to detect, verify, respond to, and clear incidents.
- Several ATIS suppliers (including ETAK and Navtech) are headquartered in the region and are interested in deploying their products in the testbed.

SURVEY OF EXISTING CONDITIONS IN THE BAY AREA

Demographics/Travel Patterns

For many years, the Bay Area has been one of the country's fastest growing regions, spurred by natural amenities and job opportunities. Over the last decade, population in the Bay Area grew from 5 to 5.6 million. A Metropolitan Transportation Commission study (MTC 1990) forecasts that by the year 2010, the population will reach 7 million. Concurrently, automobile registrations have grown even faster, increasing by 21% compared to 12% for population. The vehicle population will grow to 5.3 million by the year 2010, a 34% increase over an estimated 1990 level of 4 million (MTC 1990).

The overall trip rate during this period increased by 13%. This increase is partly due to a higher labor force participation rate per household and per person. The greater availability of cars per household also provides less incentive to take transit or to carp001 than in the past. MTC's trip generation studies showed that the growth in trips by trip purpose resembled the growth in population by demographic characteristics. In other words, growth in work trips resembled the growth in employed residents and the growth in total employment. MTC projects that by 2010, there will be 53% growth above the 1980 level in trip-making by Bay Area residents for all trip purposes. Some of the biggest growth will come from commuters traveling from bedroom communities outside of the region to job centers located within. These job centers include the San Francisco and Oakland Central Business Districts, and the high-technology centers in Palo Alto, Sunnyvale, Santa Clara and San Jose.

Transportation Infrastructure

Roads

There are 500 miles of freeways, 6,000 miles of county roads and 11,000 miles of city streets in the Bay Area (MTC 1982). These 17,500 miles of roads form a vital component of the Bay Area transportation network. The replacement cost of this system in today's dollars has been estimated at over $20,000 billion. Caltrans reports that over one-half of the Bay Area urban interstate and freeway miles are generally congested during peak hours with the number of congested freeway miles growing rapidly. Traffic growth has outstripped increases in capacity by a factor of nearly 5 to 1 over the past twenty years.

Transit

The region's 17 bus and rail operators carry approximately 1.7 million riders a day and spend more than $688 million a year. BART, AC Transit, and San Francisco MUNI are the Bay Area's largest operators and the three together expect a $26 million deficit in 1992 (MTC, 1991). At the request of the State Legislature, several studies were undertaken by MTC to evaluate the possibility of consolidating the 17 Bay Area transit agencies into three or four unified regional transit agencies. The process of consolidation is still under consideration.

BART, the region's largest rail system, has been in operation nearly 20 years. Since September, 1972, BART has carried nearly one billion passengers. The original BART facility consists of 71.5 miles of double track serving 34 stations in 15 Bay Area communities. The current expansion program includes service to new communities in Alameda, Contra Costa, and

San Mateo counties. The first phase will add 33 miles of double track and 10 stations by the year 2000. This phase of the work includes:

Ferries

Ferries have played a significant role in the Bay Area since their beginning in 1850. Ferry service was the dominant means of travel across the Bay until the completion of the Golden Gate and San Francisco/Oakland Bay Bridges in 1930. At one time, there were nine competing operators carrying 60 million passengers a year. The construction of bridges in the 1930s made conventional transit and automobile the primary travel modes among East and North Bay commuters to San Francisco. Nevertheless, at present, three ferry companies -- Golden Gate Bridge Highway and Transportation District (GGBHTD), Red & White Fleet, and Blue & Gold Fleet -- carry approximately 75,000 passengers a day with large, medium speed ferries. A ferry service is also provided by the Red & White Fleet between Vallejo and San Francisco. Although this route carries only 800 passengers daily it is seen as an excellent candidate for a high speed ferry service because I-80 is severely congested. For East Bay commuters, the discontinued service between Alameda/Oakland and San Francisco was re-established at the time of the 1989 earthquake. The Blue & Gold Fleet is heavily subsidized; it has an average daily patronage of 800 passengers. The Bay Area is now considering improved and modernized ferry services as valuable cross-Bay connectors. They could redistribute traffic from freeways and other transit systems, especially during commute hours.

IVHS INFRASTRUCTURE

At present, the Bay Area has limited capabilities for collecting traffic information. Comprehensive traffic surveillance with loop detectors, closed circuit television,and information dissemination through Changeable Message Signs, and Highway Advisory Radio, is only in place on the San Francisco/Oakland Bay Bridge (7 miles). Loop detectors have recently been installed on small segments of I-80 approaching the Bay Bridge, on Highway 101 between Miller Avenue and the Route 37 Interchange in Marin County (3 miles), and on I-680 between the Benicia Bridge and the Route 4 Interchange (3 miles). Loop detectors are currently being installed on a ten mile segment of I-880 and on the segments approaching the Bay Bridge from Oakland and San Francisco. The complete surveillance system with 40 cameras and the loop detectors on these segments of freeways is scheduled to be in operation by the end of 1992. On these segments, two loop detectors, 20 feet apart, are placed every 1/3 mile.

PLANNED IMPROVEMENTS IN THE BAY AREA

An automated Transportation Operations System (TOS) for the nine-county Bay Area freeway network is necessary for freeway surveillance and incident management. To establish a vehicle detection and incident verification system, Caltrans District 4 plans to install in-pavement loop detectors and closed circuit televisions on the entire 500-mile Bay Area freeway network by the end of the decade. The loop detectors will have two loops on each lane and will be spaced every 1/3 mile. The proposed TOS plan incorporates highly advanced, state-of-the-art technology. The TOS specifications include the standard components of surveillance, motorist information, and a management system. The traffic surveillance system will be designed to provide a real-time incident detection capability; it will include electronic roadway detectors, closed circuit television (CCTV), motorist call boxes, and a communication system for the collection of roadway detector and CCTV information. To reduce delay and secondary accidents on the freeway network, the surveillance system will be able to restore a freeway to full capacity in a timely manner. The system will also be able to provide complete information on freeway system performance.

The first stage of the Bay Area TOS is known as the “Cornerstone Project.” The project will cover 45 miles of freeways in the Central Bay Area and comprise segments of I-80 (including the San Francisco-Oakland Bay Bridge), I-580, I-880, I-980, and Route 24. The I-80 corridor through Berkeley and Oakland provides freeway access to the local business districts and to the major regional financial district in San Francisco via the Bay Bridge. It also serves the University of California at Berkeley, a major educational institution with over 30,000 students and employees.

There are two heavily traveled arterials, Frontage Road and San Pablo Avenue, that run parallel to I-80. Both can effectively serve as alternate routes to I-80.

RESEARCH OPPORTUNITIES IN THE BAY AREA

The Bay Area offers unique opportunities to experiment with inter-modal transportation services. As an example, to travel to the San Francisco financial district from the East Bay, commuters can: (1) drive alone, (2) carpool, or vanpool, or take (3) BART, (4) ferry, or (5) bus. Furthermore, the feasible number of mode combinations is also large. One can drive to a BART station, park the car, and take BART to the San Francisco central business district or one can drive the car, park at a parking lot, take a ferry to the city and then take a bus to the desired destination. If real-time schedule information is made available, more people could be attracted to the intermodal transportation options.

In another part of the Bay Area, Santa Clara County has an extensive grid of high capacity arterials. Many of the San Jose roads have been equipped with advanced signal systems, and many of the freeways now have loop detectors and ramp metering. The region would be an excellent location for ATMS/ATIS studies on coordination of freeways and arterials.

GOALS AND OBJECTIVES

The concept of an ATIS testbed entails a surveillance and database system, designed to open-architecture standards. The testbed infrastructure will collect information from several sources, including probe vehicles and loop detectors. The data will be transformed into meaningful measures of system performance such as travel times. The data will also be used to predict future travel conditions in the short-term (e.g., 15-30 minutes). The database will contain historical, real-time and predictive information on all feasible travel options, including automobile, bus, rail, and ferries. The data will be available for dissemination directly by Caltrans (e.g., through Changeable Message Signs and interchange voice response) as well as through third-parties (e.g., private traffic information services).

The goals of the ATIS test-bed are:

- To assess the potential of ATIS in improving transportation system performance based on field experiments in the San Francisco Bay Area.
- To develop an environment that catalyzes an ATIS industry, and to facilitate the deployment of ATIS technologies.
- To improve the system performance of highways and transit in the Bay Area.

The Testbed is envisioned as a public/private partnership, with Caltrans and other public agencies responsible for the installation of the testbed infrastructure, private companies responsible for the deployment of customized ATIS devices and PATH responsible for research elements. Goals specific to PATH's research program include:

- Assessment of behavioral response to ATIS, in the areas of route, departure time, and travel frequency.
- Measurement and prediction of system impacts of ATIS in a real-life transportation network.
- Analysis of human factors aspects of traveler information technologies.
- Assessment of public acceptance of ATIS technologies and evaluation of policy issues related to technology deployment and adaptation.

PATH will also serve as a technology resource to Caltrans in the following areas:

- Assistance in developing and implementing a Transportation Operations System (TOS). This will involve developing and evaluating data management technologies and computer-aided data management software.
- Development of a common database for the nine counties of the Bay Area and evaluation of institutional issues relating to data management, financing and operations of the advanced

traveler information system(s).

- Design of a system that will achieve effective traffic surveillance and management in the Bay Area.

OVERVIEW OF THIS REPORT

In Chapter 2 we present the conceptual framework of the testbed. Chapter 3 describes the criteria for selecting various field operational tests, experimental design for some of these tests, site selection and recruitment. Chapter 4 discusses the data collection, processing and management. Then, assessment of ATIS dissemination technologies is described in Chapter 5. Chapter 6 describes field operational tests. Finally, Chapter 7 presents the management plan for the ATIS testbed.

CHAPTER 2

CONCEPTUAL STRUCTURE

This chapter presents the concept of the ATIS testbed and a general framework for its design. Conceptual issues related to traveler behavior and system performance are discussed in detail. Ideas regarding technology assessment are presented and an overview of the ATIS testbed management plan is provided.

CONCEPT OF THE ATIS TESTBED

Figure 2.1 illustrates concepts of the ATIS testbed. There are opportunities to collect travel data from several sources in the Bay Area, which is in the process of installing information collection and processing infrastructure needed for providing information to individuals. This provides unique opportunities for testing new information collection, processing, and dissemination technologies. For example, to collect travel time information, vehicles can be used as probes. A Transportation Operations System (TOS) can integrate data on the available travel options. The operations system may initially be established at the local level, yet a central processing facility will be needed for comprehensive and integrated monitoring of the transportation system in the Bay Area.

The Transportation Operations System will receive information from various data sources (e.g., loop detectors, video cameras, highway patrol vehicles, probe vehicles, transit vehicles, and helicopter observation), assemble, filter and fuse this information, and process it into estimates and predictions of network performance measures such as travel times, speeds and queue lengths. In addition, qualitative information will be used to construct a complete picture of events such as incidents. Activities of establishing a TOS include the development of a database which stores real-

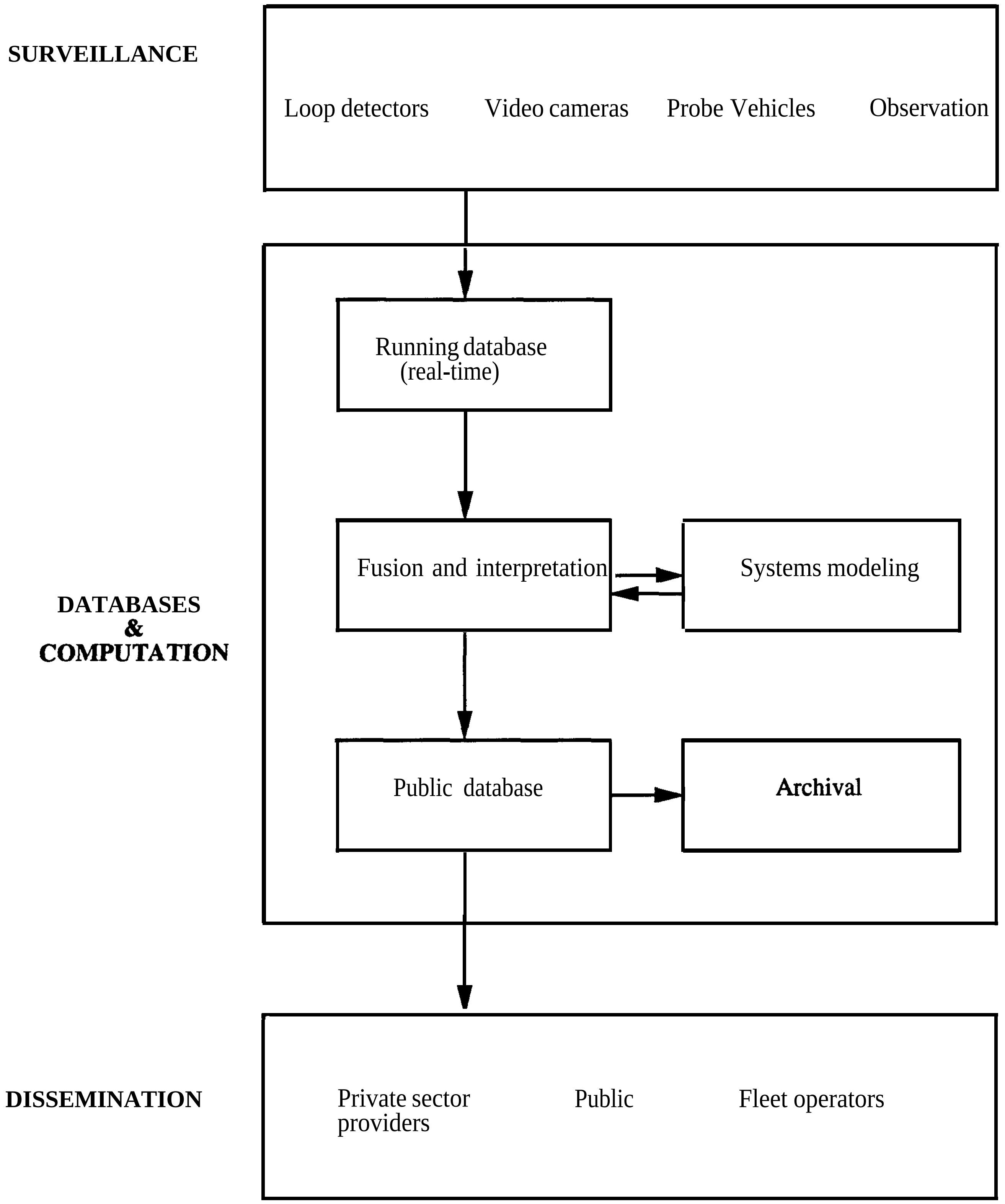

Figure 2.1 Concept of the ATIS testbed.

time traffic data on a continuous basis. Further, the TOS will also monitor perturbations in flows due to incidents. This information will be available to the interested parties which include travelers, researchers, practitioners and other agencies such as California Highway Patrol. Furthermore, the data will be archived for later studies (e.g., on planning and evaluation of projects and. safety).

FRAMEWORK FOR ATIS TEST-BED

System characteristics (such as traffic flows) are the result of interaction between travel demand and transportation system supply (Figure 2.2). ATMS/ATIS technologies will collect, process and disseminate information regarding system characteristics; this in turn may influence traveler decisions, and consequently influence system performance.

Information will be disseminated to travelers either through in-vehicle electronic devices (such as video displays for use in private automobiles or transit vehicles) or through out-of-vehicle devices such as changeable message signs, teletext and in-home/office equipment. The TOS may disseminate information according to user optimal strategies (e.g., by providing descriptive and/or prescriptive information) or system optimal strategies (e.g., by minimizing total travel time in the network and preventing diversion spillbacks to city streets). Traveler response to this information may depend on the content, type (static/dynamic, qualitative/quantitative), format (style of presentation), and attributes (such as reliability, accuracy, relevance) of the information as well as individual characteristics (socioeconomic and personality) and contextual factors (e.g., trip origin/destination, trip purpose), situational constraints and environmental conditions.

The development of an ATIS concept requires understanding of the relationships between various elements of the system. Individual FOTs will draw upon a common database, as well as data which will be unique to the experiment. The data for evaluation from demonstration studies will be based on the performance of the information system, transportation system, transit and fleet system, as well as traveler behavior. These data can be used to analyze impacts of ATIS (i.e., to understand behavioral changes caused by ATIS) and to predict the consequent changes in network

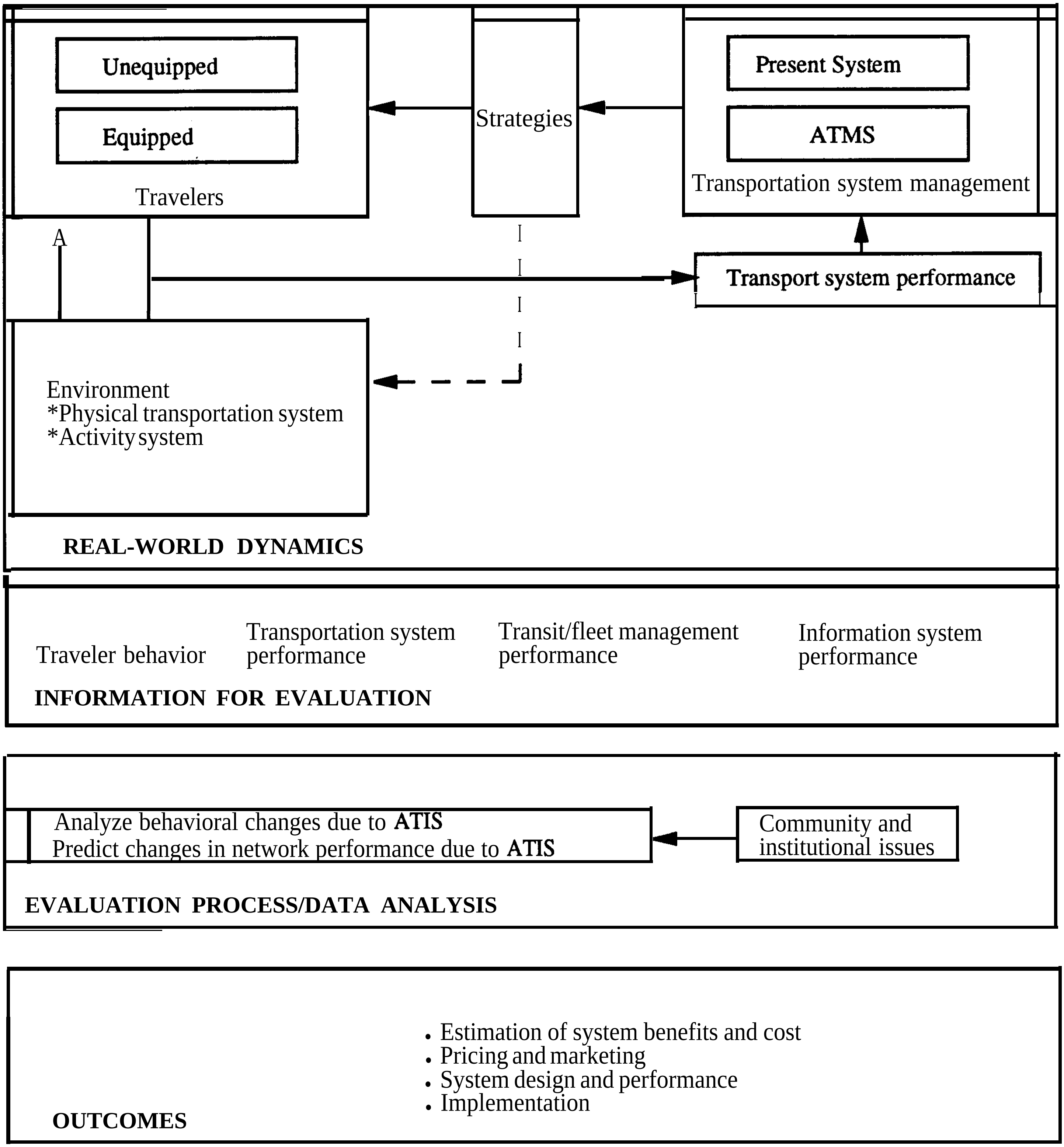

Figure 2.2 Outline of ATIS test-bed study.

performance. The purpose of estimating network changes is to allow a clear understanding of system benefits. In analyzing changes due to ATIS, the impact of factors such as communities' acceptance of traffic diverting from freeways to city streets will not be overlooked. The analysis will result in the refinement of ATIS design and performance and help in the decision regarding large scale deployment of ATIS technologies.

TRAVELER DECISION MAKING

To evaluate the effectiveness of ATIS technologies, we need to first understand the factors which influence traveler behavior--particularly, the effect of information on behavior is important. In this regard, it is useful to review the process of traveler decision making. Travel is usually undertaken to participate in activities. Individuals form perceptions regarding system characteristics based on information they receive through various sources such as radio traffic reports and ATIS (Figure 2.3). Perceptions and individual characteristics result in "preferences" among alternatives (Koppelman and Pas 1980). Situational factors such as work related constraints along with preferences then determine observable choices.

The effect of various information sources on behavior may be different (Bettman 1979). During the process of decision making, information is acquired either actively or passively from various sources. This information is used along with stored information (knowledge) in the memory to make travel decisions. Due to the limited information processing capacity of individuals, they may use simple decision rules (such as choose the minimum time route) to make travel decisions. The evaluation process may be characterized by "bounded rationality" where individuals do not necessarily search for all possible alternatives and evaluate them objectively, but consider a subset of alternatives and choose the most "satisfactory" option (Simon 1979; Mahmassani and Chang 1985). Individuals may terminate their information search depending on the importance of the decision involved, budgetary constraints, cost of additional search in terms of time and effort, and perceived value of additional information.

Information acquired by individuals has temporal and spatial aspects. Spatial knowledge,

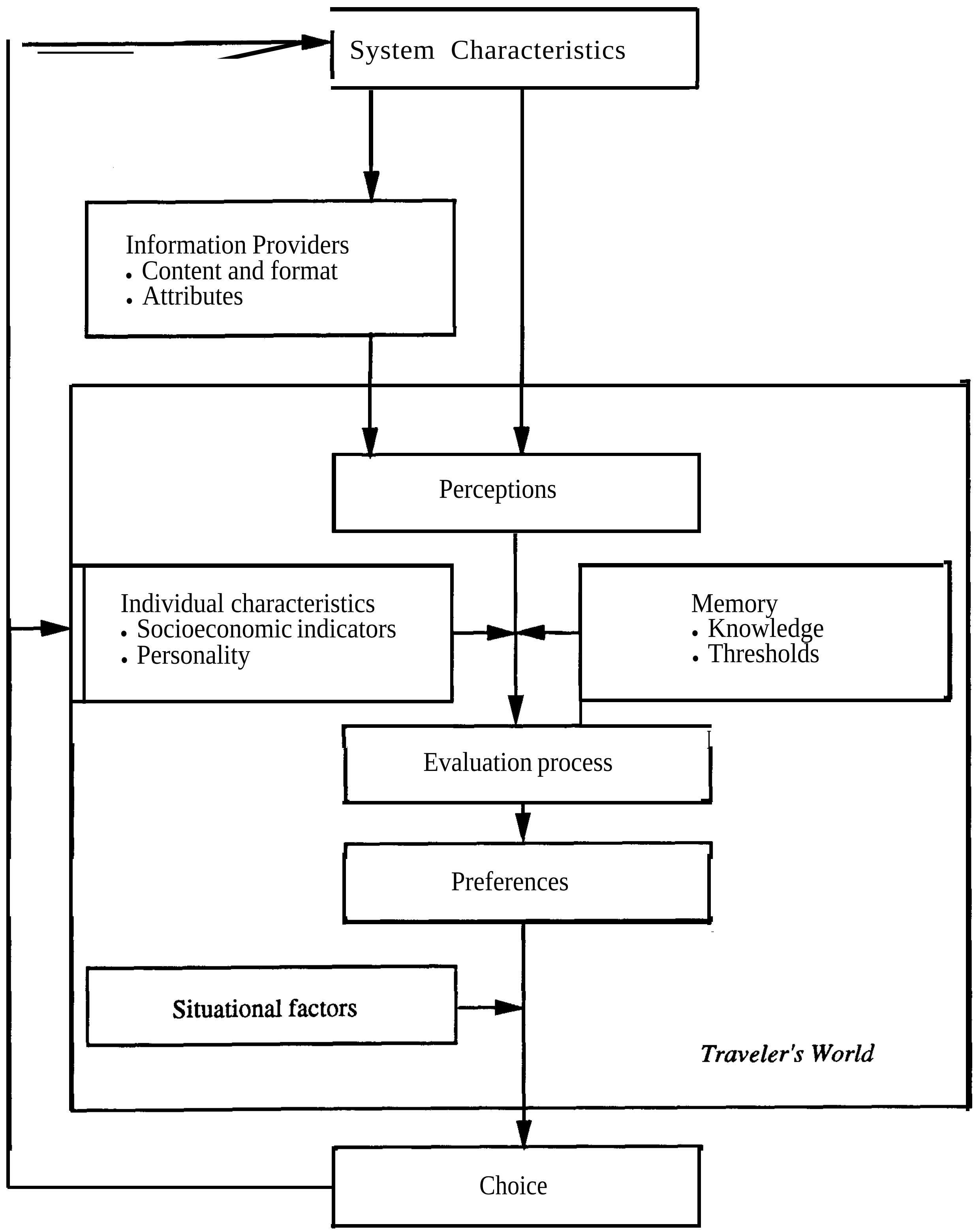

Figure 2.3 Conceptual structure for individual's decision making process.

referred to as cognitive maps, relates to internal representation of route locations in the physical environment (Golledge and Stimson 1987). Cognitive maps may influence travel behavior, for example, the number of routes known to a person influences route diversion (Khattak 1991). Temporal knowledge of travel conditions relates to an individuals' expectations of travel time and traffic congestion at different times of the day along (known) routes. Temporal knowledge is likely to influence behavior, for example, high expected congestion on a person's alternate route may hinder diversion to that route.

Due to "perturbations" in travel conditions caused by events such as incidents and inclement weather, individuals may modify their intended travel choices. For example, diversion from a "regular" route may be caused by delays due to an accident; or travelers may decide to take transit rather than their automobile due to a blizzard. Thus, expectations of travel times and delays may be important in travel decision making. Overall, the development of information systems requires investigating short-term traveler response to information and understanding the diffusion of information technologies in the future.

TECHNOLOGY ASSESSMENT

Taxonomies of ATIS Technologies

Before evaluating ATIS technologies, it is necessary to know what ATIS technologies are being developed/tested/proposed, and to develop criteria for the definition and classification of ATIS technologies (Al-Deek, Khattak, and Kanafani 1992). ATIS technologies provide different information content which may influence traveler choices and system performance. There is a need to understand how information content and technology features may influence travel decisions. To do this, we classify various ATIS technologies related to automobiles as well as transit. The development of a taxonomy of ATIS technologies will also help in:

- Selecting the appropriate technologies for operational testing.
- Modeling system performance in transportation networks and traveler response.

- Analyzing the public acceptance of **ATIS** technologies.

A taxonomy developed for automobile **ATIS** technologies is described. The basic idea of technology classification is that information content influences travel choices. Information can be either **static or** dynamic. Static information related to travel choices does not change with time, whereas dynamic information related to travel choices changes with time. Information can be further subdivided into qualitative or quantitative. Qualitative information is non-numerical (it does not include estimates of parameters such as incident duration, available parking spaces, or expected arrival time to destination), whereas quantitative information is numerical (it includes estimates of parameter values). Information content and travel choices form a two dimensional taxonomy matrix (Figure 2.4). To illustrate this matrix we give examples for some of its cells:

Cell "A" (Static Qualitative, Destination). Static information about locations of shopping centers may support choice of the shopping destination.

Cell "B" (Static Quantitative, Destination). Static information about travel distances to shopping centers may support the choice of the shopping destination.

Cell "C" (Dynamic Qualitative, Destination). Real-time information about whether or not a pharmacy is open supports destination choice of a person in need of medication.

Cell "D" (Dynamic Quantitative, Destination). Real-time information about waiting times at restaurants supports the choice of a restaurant destination.

The taxonomy matrix and technology features form an inventory sheet that will be used in a comprehensive survey of the **ATIS** technologies. Each **ATIS** technology will have a separate filled out sheet as shown in Figure 2.4. This inventory task will help evaluate the different **ATIS** technologies.

Assessment of ATIS Benefits

There have been numerous studies during the last decade to evaluate the benefits of route guidance of **ATIS** technologies (see, for example, Kobayashi 1979; Jeffrey **1987a,** 1987b;

TECHNOLOGY : ____________________

MANUFACTURER/SPONSOR: ____________________

INFORMATION TYPE / CHOICES	STATIC		DYNAMIC	
	QUALITATIVE	QUANTITATIVE	QUALITATIVE	QUANTITATIVE
DESTINATION	A	B	C	D
MODE				
DEPARTURE TIME				
PRE-TRIP ROUTE				
EN-ROUTE DIVERSION				
PARKING				
TRIP CHAINING				

ATURES :

☐ PORTABLE c l NON-PORTABLE

☐ IN-VEHICLE ☐ OUT-OF-VEHICLE

☐ AUDIO ☐ VISUAL

☐ SINGLE MODE INFORMATION ☐ **MULTI-MODE INFORMATION**

☐ EMERGENCY COMMUNICATION ☐ NO **EMERGENCY** COMMUNICATION

☐ ONE-WAY ☐ TWO-WAY COMMUNICATION

RESERVATION OF ☐ **DESTINATION** ☐ MODE ☐ PARKING

ROUTE OPTIMIZATION BY ☐ CENTRAL COMPUTER ☐ IN-VEHICLE COMPUTER ☐ NONE

CENTRAL CONTROL OF TRAVEL CHOICE ☐ YES c l **NO**

VEHICLE LOCATION ☐ KNOWN ☐ **UNKNOWN**

NUMBER OF VEHICLES USED IN THE TEST: ____________

TECHNOLOGY STATUS: ____________________

Figure 2.4 Taxonomy of automobile **ATIS** technologies.

Al-Deek et al. 1991, 1989; and Khattak 1991). However, relatively few efforts have focused on the evaluation of ATIS benefits in the field.

ATIS benefits can be viewed from the perspective of the individual (user) and the transportation system as a whole, as follows.

User Benefits

ATIS may benefit users in terms of travel time savings and travel time related costs (e.g., vehicle operating costs including wear and tear) that can result from a decrease in excess travel of unfamiliar drivers (Kanafani 1987). Moreover, changes in travel decisions (destination, mode, departure time, route, enroute diversion, parking and trip chaining) due to unpredictable delays resulting from incidents or natural bottlenecks may provide significant benefits.

Other benefits may also accrue from ATIS, among them are:

- Increased knowledge of travel options, e.g., "yellow pages" information may allow increased destination options; similarly awareness of options may cause a mode shift.
- Reduced anxiety--even if travelers do not change their travel decisions (Khattak 1991).
- Increased reliability, particularly in arrival at destination.
- Enhanced ability to avoid congestion, that is, travelers may want to avoid queuing delay, even if travel times are the same.
- Improved ability to communicate during emergencies.
- Reduced possibility of getting lost.

In the long-term, ATIS may improve mobility by influencing automobile ownership, and work and residential location choices.

Changes in the travel patterns of ATIS users can benefit non-users. For example, in incident conditions, informed travelers may change their travel patterns (e.g., they may divert to alternate routes); this may reduce incident duration and result in less delay to (uninformed) non-users.

System Benefits

System benefits of ATIS may include reductions in travel time, pollution and energy consumption and improvement in safety. Previous ATIS evaluation studies have largely focused on benefits from route guidance. The results from these studies suggest that route guidance is likely to be more useful under non-recurring (incident) congestion. However, the system benefits of route guidance are marginal under conditions of recurring congestion (projected travel time savings were in the vicinity of 10%). Under incident conditions, travelers usually lack information about the severity and duration of incidents and their location vis-a-vis the rest of the network. Therefore, travelers are insufficiently informed to make appropriate route choice decisions. By disseminating incident information to potential travelers long before they approach incident locations, it may be possible to reduce congestion. Specifically, by altering trip patterns, including departure times, traffic can be spread over time and space with benefits accruing not only to informed users but also to uninformed travelers who encounter less traffic.

System benefits will likely depend on the strategy for dissemination of real-time information, e.g., routing traffic to minimize total travel cost in the network compared to routing traffic to achieve user equilibrium. In addition, longer-term system benefits may depend on the "diffusion" of ATIS technologies.

Needed Research

To understand the potential for ATIS, we need to know the magnitude of individual and system benefits. Specifically, the following will be evaluated:

- Short-term user benefits (travel cost and psychological) from changing travel choices in various contexts, e.g., familiar and unfamiliar environments.
- Long-term user benefits from relocation of residence and work and changes in automobile

ownership.

- System benefits that accrue from short-term changes in travel choices such as destination, mode, departure time, and route.
- Long-term system benefits other than travel time savings such as reduction in pollution, energy consumption, and impact on travel safety.
- Route guidance benefits that result when different information dissemination strategies are implemented under incident conditions.

Other issues such as public acceptance (e.g., impacts of redistributing traffic to city streets), equity (in redistribution of traffic and availability of access to ATIS), economic efficiency (cost recovery), and liability (in case of an accident while following ATIS advice), will be addressed as part of the technology assessment (Kanafani 1987). Furthermore, policy issues that need to be addressed are: how are the benefits distributed between guided and unguided travelers? When and how will traffic guided with ATIS be better off than unguided traffic? How will the incremental deployment of ATIS technologies (i.e., diffusion) influence the perception of user benefits?

ELEMENTS OF ATIS TEST-BED

The ATIS testbed would be a regional laboratory jointly managed by Metropolitan Transportation Commission, the California Department of Transportation (Caltrans), and Partners for Advanced Transit and Highways (PATH). The joint management board will establish a framework for conducting research and field operational tests (FOTs). The FOTs will test ATIS technologies related to private automobiles (e.g., in-vehicle route guidance systems), vanpools/rideshare, transit, and fleets. The testbed is intended to provide the facilities and know-how for technology organizations such as Siemens and Motorola to test their products. Furthermore, the testbed will encourage partnerships and joint ventures between private and public organizations. For example, it will offer opportunities for interested transit agencies and city governments to collaborate in testing ATIS technologies offered by private companies.

The research activities would be closely tied to the FOTs, i.e., researchers will play a major role in addressing conceptual, methodological, and evaluation issues related to FOTs. Demonstration studies are expected to be multi-year research efforts and provide opportunities for an on-going design and evaluation process. Initial evaluations can be used as inputs to later ones, as well as for refining the design and methodologies of the experiments. Therefore, in conducting demonstration studies a framework for identifying tasks performed before, during, and after the studies is needed. Particularly, to conduct FOTs successfully, the tasks of establishing a TOS, managing the incoming data (collection and processing), selecting sites for FOTs, and recruiting individuals will precede field operational testing and follow-ups. (Some of these tasks, such as data management, will be on-going throughout the FOT.)

SUMMARY

The ingredients of the ATIS testbed include developing the capability of network monitoring, processing and integrating incoming data at a Transportation Operations System center, and disseminating/archiving this information. The testbed will allow a comprehensive research program to be intertwined with the field operational tests. Further, it will encourage private technology developers to participate in the FOTs and contribute to research efforts.

CHAPTER 3

DESIGN AND ANALYSIS

This chapter provides guidelines for designing and selecting experiments in the ATIS testbed. First, an overview of the basic steps in developing experiments is given. Then, general criteria for the selection of experiments are discussed. After this, examples are presented to illustrate various concepts of experimental design. Finally, site selection and recruitment issues arc discussed.

BASIC STEPS IN EACH FOT

For each FOT, the Principal Investigator will be responsible for identifying goals and objectives. A statement of the problem will be provided and the following will be addressed:

- The motivation and scope of the work. The relationships between the proposed study and other testbed experiments as well as similar research in the literature must be stated.
- The conceptual structure of the experiment. The components of the system under investigation will be defined. The relationships among system components will be hypothesized.
- The methodology of the experiment. The procedure for investigation and the experimental design will be outlined. The reasons for selecting a particular methodology will be elaborated.
- The pre-experiment analysis. In some cases, there may be opportunities to analyze some aspects of the problem before conducting the field experiments. The analysis may result in refinement of the conceptual structure and the methodology.[1]

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[1]For example, the laboratory simulation studies related to human factors currently underway at the University of California at Davis (Kitamura aud Jovanis 1992) will help in developing initial designs for ATIS interfaces. Similarly, precursor computer simulation and behavioral studies underway at the University of California

- The analysis of data acquired during the experiment. The data acquired during the field operational tests will be analyzed. Early analysis allows the detection of errors and sometimes it may result in **revisions/refinement** of the aforementioned steps. The analysis should result in meaningful conclusions and useful recommendations with regards to **ATIS** deployment.

SELECTION CRITERIA FOR FOTs

Individual projects will be selected based on several criteria. The criteria for project selection are based on:

- Expected benefits, from the standpoint of what researchers, practitioners, the State of California ***and*** the technology suppliers will gain from the project.
- Contribution of the project to transportation practice and to the body of knowledge on **ATIS.** This will be determined through soliciting opinions of researchers and practitioners.
- **Originality** of the project.
- Consistency with the goals, objectives and products (deliverables) of the **ATIS testbed.**
- Clear definition of the methodology, research plan and the project schedule.
- Financial and technical feasibility of the project.
- Qualifications of the project team to carry the project to successful completion. The expected time for completion of the project should not exceed the time frame of the **ATIS testbed.** Also the specific experiments will be scheduled in order to be consistent with schedules of other experiments.
- Whether the project is a true collaborative effort (e.g., between public and private sector) .

EXAMPLES OF EXPERIMENTAL DESIGN

To illustrate concepts of experimental design, two examples are provided.

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at Berkeley will develop an initial understanding of ATIS impacts (Al-Deek, Khattak, and Kanafani 1992).

Behavioral Experiments

A majority of FOTs will have some component related to behavioral response. The FOTs provide an opportunity to observe behavioral changes due to ATIS in the field. This section describes design considerations for understanding traveler response to ATIS.

The Concept

Response of the travelers who receive ATIS is likely to be influenced by information content and type explained earlier. In addition, the following factors may also influence decision making:

Information Format. Some presentation styles may be preferred more than others (depending on the context). For example, Dudek et al. (1983) have found that drivers preferred terse messages compared with conversational style.

Information Attributes. Perceived attributes of information are likely to influence the extent to which individuals may use information. Specifically, credible, reliable, accurate, timely and relevant information is more likely to influence decision making.

Prescriptive Information. ATIS may give prescriptive information (e.g., advice on the best alternate route) probably in addition to descriptive information. Depending on the context, the effect of prescriptive information on travel decisions may be different from descriptive information. For example, when a traveler is unfamiliar with the surroundings he or she may be able to make better use of prescriptive information, whereas in familiar areas the traveler may prefer descriptive information. Regarding effects of prescriptive information, it is important to study the factors which influence the acceptance and rejection of ATIS advice. From a systems perspective, prescriptive information can be based on implementation of user optimal or system optimal strategies. In case the prescriptive information is based on user optimal strategy, it will likely result in improvement of a driver's travel time; however, in case it is based on system optimal strategy, it may mean longer travel times for some drivers. In such cases incentives may be needed to convince drivers to follow advice.

Design of Behavioral Experiments

B e f o r e

Experiments can be either natural, where researchers have little or no control, or they can be laboratory, where researchers have relatively greater control. The validity and generalizability of laboratory experiments is difficult to determine, however. For the **FOTs,** some degree of control will be necessary to analyze relationships clearly; yet, the frequency of intrusions (e.g., by surveying system subscribers) will be kept to a minimum.

To understand the short-term impacts of **ATIS** on traveler behavior, a before-and-after control group design is proposed. The control group will be equivalent to the experimental group in terms of relevant criteria (e.g., socioeconomic characteristics and trip patterns) and it will be useful in clearly identifying the effect of **ATIS** by allowing comparison of behavior ***across*** drivers of equipped and unequipped vehicles. Furthermore, the "before" measurements are necessary because they will provide a "base" for comparison in the future, i.e., comparison of the ***same*** individual's behavior with and without **ATIS.**

The **testbed** will provide opportunities to conduct demonstration experiments in parallel. To control for possible adverse effects of separate experiments conducted concurrently, a management strategy will be designed. Specifically, the management will study the possibility of interference before new experiments are commissioned. If a new experiment is found to significantly interfere with ongoing experiment(s), then the management can recommend to either redesign the experiment appropriately or scrap it altogether.

Longitudinal Panel

To study the long-term behavioral impacts of **ATIS** and develop a fundamental understanding of how short-term decisions such as mode, route and departure time decisions change over time, a longitudinal panel will be used. Only by following individuals' behavior over the long-term can the impact of information technologies on decisions such as automobile ownership and relocation of residence be understood. Besides the ability to explore dynamic effects, the main advantages of a panel are greater accuracy compared with cross sectional studies, analytical sophistication in analyzing data, and the ability of researchers to have in-depth interviews with panel members (participants will be compensated for their time).

A combination of "true panel" (where participants are asked the same questions repeatedly) and "omnibus panel" (where participants are asked different questions in successive waves) will be used. The questions about trip patterns and socioeconomic characteristics will be repeated, whereas questions about impacts of advanced technologies can vary.

Analysis

Demonstration studies will evaluate, in a structured manner, the effects of various information aspects on traveler behavior. Specifically, to evaluate the effects of information content, type and format on decision making, factorial designs will be suitable because they allow the exploration of interaction effects. For example, travelers may prefer prescriptive information in unfamiliar surroundings but they may prefer descriptive information in familiar contexts. Repeated observations of the experimental group will be necessary to separate the effects of information content, type and format. Multivariate statistical techniques such as discrete choice analysis and longitudinal data methods will be used to analyze the decisions of travelers.

Freeway Service Patrol Experiment

The Concept

This experiment will measure system benefits of improved incident management through faster incident detection, verification, response, and clearance using Freeway Service Patrol (FSP) vehicles. The concept is to utilize FSP special tow trucks as roving probes by assigning a number of them to freeway segments (typically 5 miles in length) in order to quickly detect and verify incidents. This will expedite the incident detection and response process. The **FSPs** who encounter incidents can provide accurate and intelligent information to the Computer Aided Dispatch (CAD) system in order to dispatch the proper incident response team, send the appropriate clearance equipment, and implement efficient clearance strategies, e.g., closing the entire freeway section. A reduction in the amount of time needed for incident detection, verification, response, and clearance will result in a decrease in the total incident duration, and consequently, the cumulative vehicle-hours of delay in the system.

Design of the FSP Experiment

Detailed incident data on several freeways will be collected during two time periods: "before" the FSP is implemented and "after" it is implemented. The incident data includes variables such as: exact location of the incident and freeway direction; times of incident detection, verification, response, and clearance; type of incident, e.g., accident, CHP citation; number and characteristics of vehicles involved in the incident; weather and environmental factors, e.g., fog, pavement skid resistance; and detailed information about the rescue team and clearance equipment. Similar types of "before" and "after" incidents (e.g., accident blocking one lane, involving two vehicles, and no injuries) will be compared to determine if there is a reduction in times for incident detection, verification, response, and clearance. To evaluate improvements in freeway system performance caused by FSP probe vehicles, cumulative hours of delay will be calculated and compared during equivalent "before" and "after" time periods.

The experiment will test for seasonal effects through follow up studies (e.g., repeat the study one year later) and/or control group comparisons. In the latter, the FSP will be implemented at similar sites, e.g., same geometric design and comparable traffic volumes, but the implementation in these sites will be during non-overlapping time periods.

Analysis

Statistical techniques will be used to determine if there have been improvements (or reduction) in times needed to detect, verify, respond to, and clear the incident. Data on traffic counts and occupancy, collected through Model 170 controllers, will be used for calculating cumulative congestion using existing and/or developed techniques. Methods for evaluating cumulative congestion will be developed based on empirical data. For example, one can utilize cumulative arrival and departure curves (commonly used in applications of queuing theory) to calculate system cumulative hours of delay.

An important issue is to study how the cumulative hours of congestion is influenced by the number of **FSPs** on a freeway segment. The experiment will provide design guidelines regarding the effect of changing the number of **FSPs** on cumulative delays, suitable deployment and circulation of these vehicles on freeway sections, stations for **FSPs,** and so on.

The analysis will include effects of **FSPs** on safety, particularly reduction of secondary accidents. For example, at some freeway locations, **FSPs** mav be able to minimize the chance of secondary accidents caused by private tow trucks who, sometimes unauthorized by CHP, speed to get to the incident scene, and compete to provide the towing service. Thus, we may be able to notice reduction in secondary accidents (while accounting for confounding factors such as weather **conditions).**

SITE SELECTION

The following general criteria can be used for the selection of sites in the Bay Area

- Is traffic congestion a serious problem?
- How much surveillance infrastructure is available‘?
- Are alternative modes and routes available?

Initially, the experiments can focus on a few sites. This will improve efficiency in management and may reduce the cost of individual experiments. After the initial testing, the actual deployment of **ATIS** technologies can be more diffused covering other areas in the San Francisco region. Two Bay Area sites were identified for initial experimentation. The San Jose area seems appropriate for automobile **ATIS** experiments due to traffic congestion, availability of operational loop detectors, and the presence of several freeway and surface streets (with surplus capacity) as alternate routes. The Bay. Bridge/I-80 corridor seems appropriate for multimodal experiments because of the adverse congestion problem, the availability of surveillance systems and the availability of multimodal alternatives such as BART, park-and-ride, car/van pools and ferries. Budget constraints will also influence the size of the selected site for specific FOTs. For example, lack of financial resources may reduce the length of the freeway segment in the FSP experiment.

In addition to the general criteria, some FOTs may require additional criteria--which will depend on the nature of the experiment. To illustrate the application of the general and FOT-specific criteria, the following examples are given.

Freeway Service Patrols

Factors which influence site selection for this experiment are:

Level ***of freeway congestion.*** Congested freeway segments are preferred because they are likely to have a higher frequency of incidents than less congested segments.

Availability of 170 controller data. The freeway segment in the selected site is expected to have continuous collection of traffic data, i.e., through loop detectors.

Luck of specialized towing service in thefreeway segment. The effect of FSP will be more discernable where special towing services are not available. For example, there is a specialized and effective towing service on the Bay Bridge which is continuously monitored by the toll plaza TOC; therefore, the Bay Bridge does not meet this criterion.

Number of FSP vehicles available for the test. An important factor in determining length of the freeway segment which can be monitored by the FSPs for effective incident detection is their number. Shorter freeway segments will be preferred if the number of FSP vehicles is small.

Representativefreeway segment. Sites or corridors with typical freeway segments in terms of geometric design will be preferred because this will facilitate comparison of results.

Diversion of ATIS Equipped Vehicles

The purpose of this experiment is to divert traffic to alternate routes under incident conditions. Factors which influence site selection for this experiment are:

Availability of feasible alternative routes for diversion. The feasibility of alternate routes is determined by excess capacity and whether major arterials exist parallel to the freeway network. Availability may also be constrained by whether or not there will be opposition to traffic diversion by localities surrounding the alternate routes.

Monitoring of traffic on alternative routes. To observe any system effects, traffic needs to be monitored on the main corridor route as well as on alternate routes.

Availability of experimental subjects. The number of ATIS equipped travelers that must be diverted to observe system benefits will be large in some cases. Therefore, the selected area is expected to generate a sufficient number of individuals who are willing to participate in the experiment.

A simple road network that meets the above criteria consists of two bridges between urban areas. Specifically, the San Mateo and Dumbarton bridges connect Hayward/Fremont and San Mateo/Palo Alto (a third alternative is to go through San Jose). A large number of commuters who work in Silicon Valley and use these bridges may be willing to participate in this experiment for two reasons: accessibility to real-time information which will help in route choice and familiarity with computer technologies. Monitoring of traffic crossing the two bridges is a simple task once sensors are installed on the bridges. It will be possible to measure queue length, speed, and changes in capacity on a real-time basis both under recurring and incident congestion conditions on the two bridges. The effects of diverting ATIS equipped vehicles from one bridge to the other can be evaluated and also the number of ATIS equipped vehicles needed to achieve a certain level of system improvements can be estimated (Al-Deek 1991).

Multimodal Real-Time Information

The purpose of these field operational tests is to examine the benefits of real-time multimodal information, e.g., multimodal trip reservation, delays in transit due to emergencies, and availability of park-and-ride spaces. It will be appropriate to select a site where transit and

High Occupancy Vehicles are competitive with autos driven alone possibly because of a lack of alternative routes, existence of severe parking problems, and provision of incentives for HOV's such as free tolls and availability of HOV lanes at freeway bottlenecks.

A good site for this field operational test will be the Bay Bridge; it provides multimodal interaction among bus, BART, vanpools, and autos; it has a park-and-ride facility; there is congestion during peak travel; and auto users experience a severe parking problem in downtown San Francisco.

RECRUITMENT OF INDIVIDUALS

Experiments related to private automobile users will select a representative sample of the driving population. Data from secondary sources such as utility records, vehicle registration records, and county travel surveys can be used to determine the sampling frame and design a selection scheme. Specifically, knowledge of trip patterns, particularly origins and destinations, and socioeconomic characteristics will be used to stratify the population into groups. Simple random sampling can be used for each stratum.

Recruitment studies will investigate the monetary and non-monetary incentives needed for (1) participation in the experiment and (2) following system optimal advice even if it means longer travel times.

In the case of multimodal experiments, individuals who have real transit and rideshare options vis-a-vis automobile will be recruited. For example, the individuals who are selected should have the commute time by transit not larger than X% of the commute time by automobile. The methods for obtaining a representative sample will be similar to the automobile user experiment.

It is highly desirable to avoid biases in sample selection and attrition. However, some groups in the sample may be over-represented, e.g., in auto user experiments, people who travel extensively may be more likely to participate because ATIS will be more beneficial for them. Such biases will be “corrected” through statistical analysis.

The sample size will depend on the objectives, context and desired generalizability of the FOT. In some cases it may be appropriate to use "sequential" sampling (where the sample size is not determined a-priori) and in others to use "fixed-size" sampling. For exploratory studies, smaller sample sizes will be acceptable, however, if the objective is to understand the impacts of ATIS across the driving population, then statistically larger sample sizes will be required.

The traditional methods of determining sample size depend on variability of relevant parameters in the population. The traditional approach is simple and adaptable; however, it does not consider the cost of sampling explicitly. On the other hand, the Bayesian approach is conceptually superior because it depends on the expected payoff and cost of sampling. It is premature to suggest which method will be more suitable for particular experiments, however, the important point is that alternative sampling methods should be considered for specific FOTs.

SUMMARY

Each FOT will be required to have clear objectives and methodologies. The proposals for FOTs will be evaluated according to criteria such as expected benefits, contribution of the project, consistency with goals and objectives of the testbed, and financial feasibility of the project. It is expected that the basic principles of experimental design will be applied to individual FOTs. Example FOTs are given to illustrate these principles. It will be important to have a longitudinal panel to assess dynamic effects over the long-term, and provide a basis for overall evaluation of information technologies.

Before commencing FOTs, pre-analysis will be needed. For example, the FOTs will be conducted at sites selected according to general and experiment-specific criteria. Recruitment of individuals for participation in experiments and/or surveys will be done systematically to avoid possible biases.

CHAPTER 4

DATA MANAGEMENT

The ATIS testbed will develop the capability for providing individuals and organizations with reliable historical, real-time and predictive information. Reliability of travel information is directly related to the accuracy of procedures used for estimation and prediction of network performance such as travel times on highway links and lengths of unexpected delays caused by incidents. This chapter discusses procedures for collection and processing of traffic and transit information. Before this, a detailed review of the existing infrastructure in the Bay Area is given and the proposed and on-going information collection projects are discussed.

EXISTING AND PROPOSED SURVEILLANCE INFRASTRUCTURE

Currently, two traffic surveillance systems are operational in the Bay Area One is an infra-red monitoring system on the upper deck of the San Francisco Bay Bridge (the lower deck will be monitored by 1994). The other is an interim Traffic Operations Center in Vallejo.

The Bay Bridge

The upper deck of this bridge is equipped with optical detectors spaced 600 feet apart (a total of 40 stations). An infra-red ray is beamed across the five lanes of traffic; this information is processed and used for incident detection. The system seems reliable because it accurately measures occupancy. A small Traffic Operations Center (TOC), located next to the toll plaza, monitors the upper deck When an incident is detected, Closed Circuit Television (CCTV) cameras are used for confiiation. Personnel at the TOC then dispatch specialized tow trucks for clearing the incident.

Changeable Message Signs (CMSs) installed on the bridge are used to disseminate information. This can help drivers in changing lanes, however, the usefulness of CMSs is limited because travelers do not have the opportunity to divert by the time they see the signs. This problem may be circumvented soon because work on installing CMSs at all freeway-to-freeway interchanges approaching the Bay Bridge is underway and is likely to be completed in 1992. In addition, about 40 to 50 CCTV cameras will be installed by 1993.

Traffic Operations Center in Vallejo

An interim TOC is presently operated by the California Highway Patrol (CHP) in Vallejo. It receives and processes 911 cellular telephone calls regarding incidents. After incidents are detected, the CHP responds by dispatching (nearby) patrol vehicles. It also cooperates with Caltrans in clearing incidents.

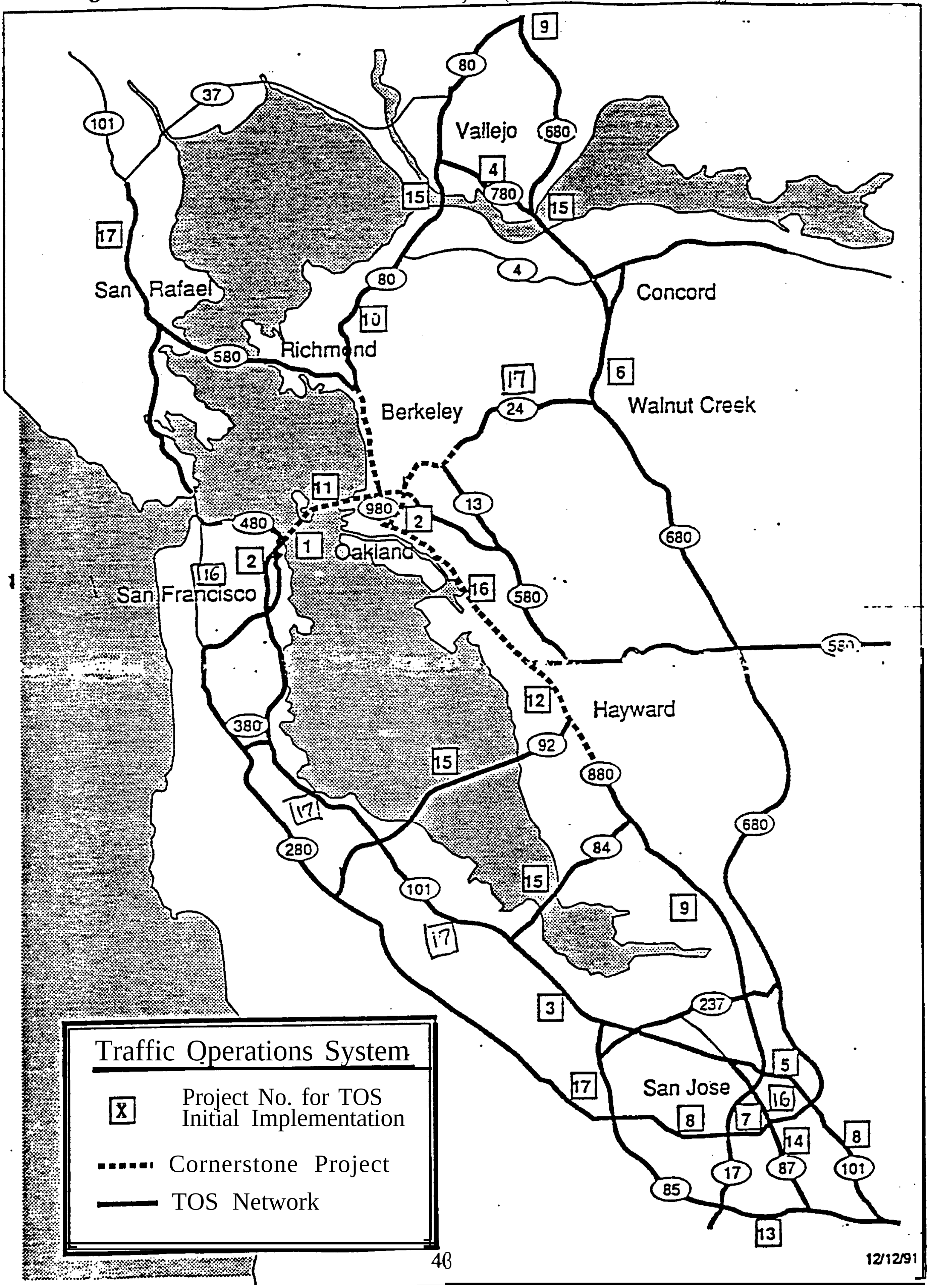
Proposed and Ongoing Bay Area Projects

By the end of this decade, Caltrans plans to monitor 512 miles of freeway through surveillance technologies-such as loop detectors (about 35,000 loop detectors will be installed) and television cameras (Figure 4.1).[1] About 45 miles of freeways will be covered by the Cornerstone Project (see project schedules in the Appendix). Moreover, all Bay Area bridges will be monitored by 1996. Information from surveillance systems will be used for traffic control (e.g., by implementing ramp metering in Santa Clara county) and for dissemination (e.g., by installing CMSs in Santa Clara county).

A number of loop detectors have already been installed in scattered locations in the Bay Area. For example, Highway 101 has about 42 operational loop detectors and San Jose has many more loops which are operational. The loop detectors in San Jose allow metering at approximately 45 ramps. However, to use the loop detector data effectively for ATIS, a central processing facility is needed. A Bay Area Traffic Operations System (BATOS) is planned to be operational by

[1]This information is based on our meetings with Caltrans District 4 officials.

Figure 4.1 Illustration of Coinerstone Project (Source: *Cornerstone Staff*)



1996.

TECHNOLOGIES FOR DATA COLLECTION

The highway transportation system consists of freeways and arterial/local streets (Figure 4.2). The freeways are normally managed by state authorities, and are policed by the California Highway Patrol (CHP); in some urban areas, freeways have ramp control. The arterial/city streets are normally managed by the local authorities. They are patrolled by the city police and some streets are signalized. In terms of surveillance, typically more attention has been given to monitoring freeway conditions. This may also be reflected in the policy of installing loop detectors on Bay Area freeways. To manage the highway system properly, particularly in incident conditions, there is a need to disseminate information on freeways as well as the arterial/city streets. In this regard, vehicles can be useful as probes in monitoring conditions on unmonitored arterial/city streets.

The information sources available to transportation system managers in a BATOS can be classified as follows:

Infrastructure-Bused Data Sources. Various infrastructure-based sources collect relevant travel data. These sources may include loop detectors, video cameras, ramp metering and signal operations. Generally, infrastructure-based data sources require large monetary investments.

Non-Infrastructure Bused Data Sources. These sources can supply relevant travel data but they do not require large monetary investments. These sources may include probe vehicles (e.g., ATIS equipped automobiles, fleet/transit vehicles, Freeway Service Patrols-FSPs) with Automatic Vehicle Identification (AVI) technologies, police and emergency operations, cellular phones, private traffic services, devices for monitoring other communications such as CB radios, maintenance/construction schedules, and transit operators and schedules.

After information is received from various sources, it will be filtered, assembled, fused, and processed into estimates and predictions of network parameters such as travel times. This information will be disseminated to individuals, agencies and the private sector.

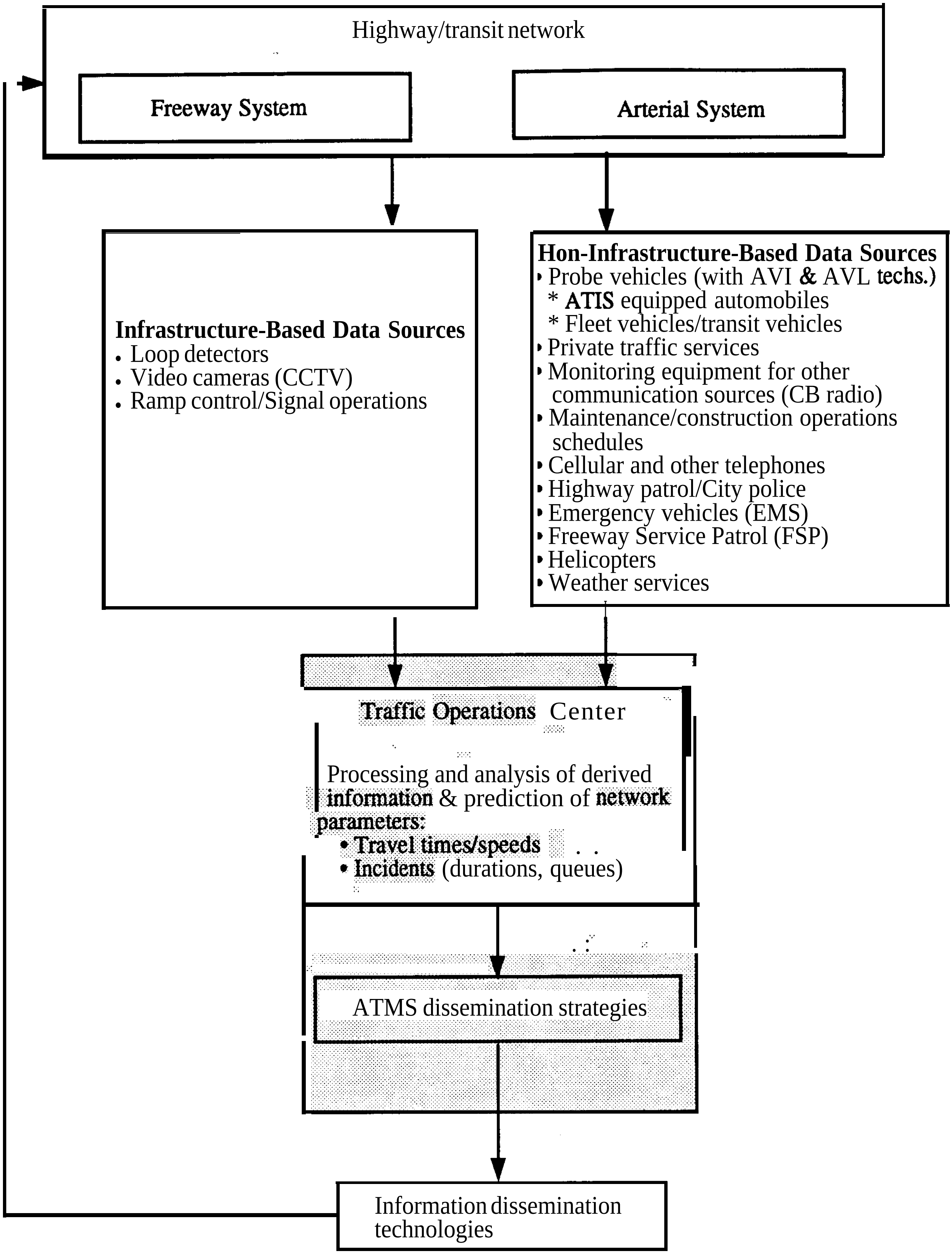


Figure 4.2 Conceptual diagram of technologies used for data collection and information dissemination.

BAY AREA REGIONAL TRAVEL INFORMATION DATABASE (BARTID)

A conceptual framework for Bay Area database management is shown in Figure 4.3. Database management involves data collection, data processing at the Bay Area Traffic Operations System (BATOS), dissemination of information to various entities, and storage of information in a Bay Area Regional Travel Information Database (BARTID) for use by practitioners and researchers. The database will support an "open testbed" environment in which technology developers can test their traveler information devices by accessing the same database.

Traffic data will be collected from the sources discussed earlier. Particularly important is the collection of data through infrastructure based sources such as loop detectors, cameras, and ramp/signal control, which will be available before and during the testbed activities because several projects related to construction/installation/operation are close to completion. In addition, probe data will also be available probably on a regional basis through the following means:

Vehicles equipped with Automatic Vehicle Identification tags. ***The*** Bay Area is in the process of implementing a region-wide Automatic Vehicle Identification (AVI) system to enhance toll collection on its bridges. The location of participating AVI-tagged vehicles can be traced in the network to monitor link travel times on a real-time basis.

Transit vehicles. Travel time on the transit network links can be reported by transit vehicles to BATOS.

Vanpools equipped with communication devices (cellular phones) or AVL-Automatic Vehicle Location (e.g., deadreckoning and GPS). The vanpools will be able to measure link travel times on HOV as well as other lanes.

Vehicles equipped with Advanced (In-Vehicle) Driver Information Systems (ADIS). Autos equipped with information technologies (supplied by Siemens and Motorola, for example) can send detailed data to BATOS, e.g., vehicle start and end trip times, vehicle speed, number of stops made by the vehicle, its latitude, longitude, and heading.

Freeway Service Patrol Vehicles. The FSPs will be used primarily for incident detection,

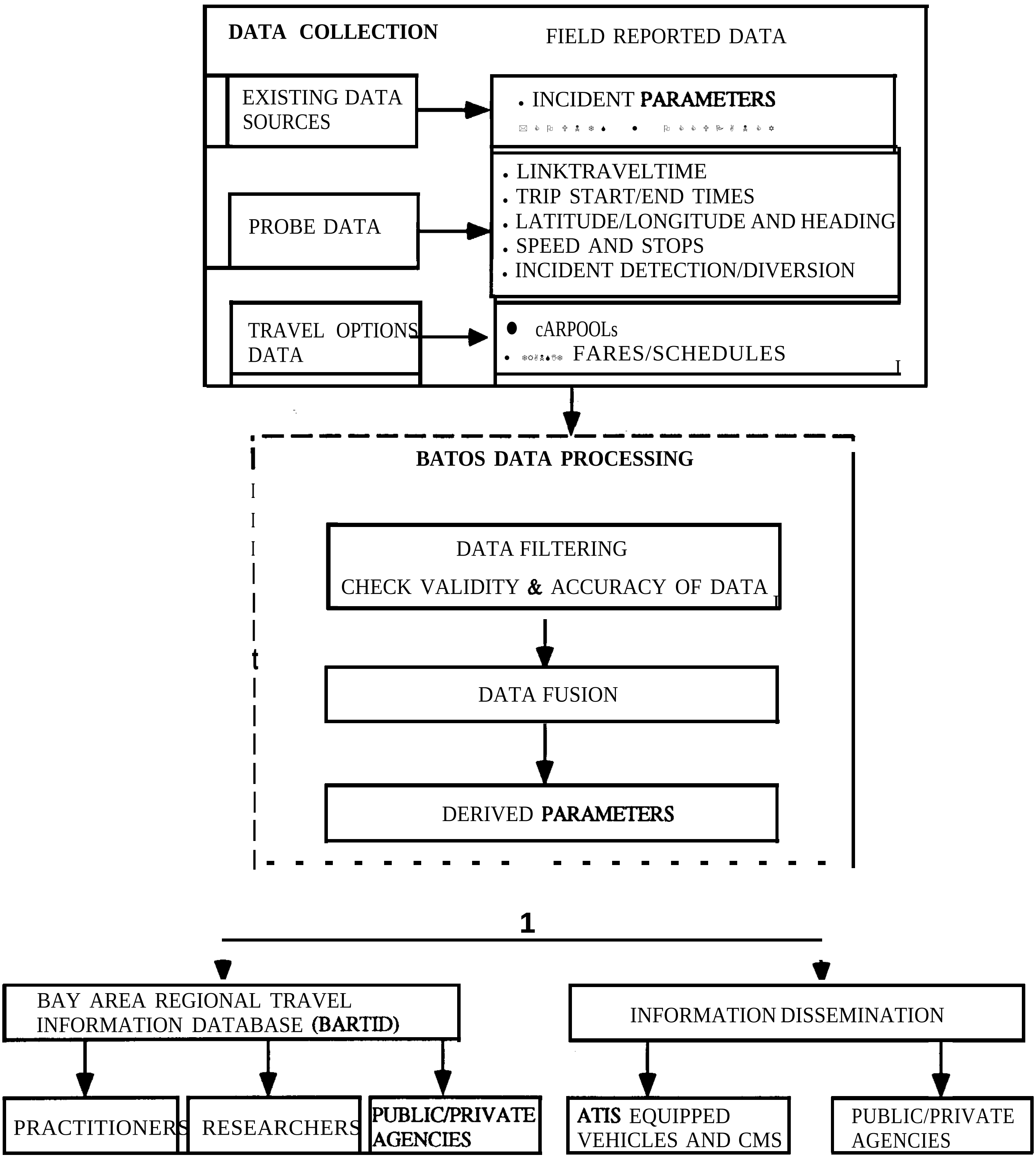


Figure 4.3 Database management for the Bay Area ATIS testbed.

verification, response and clearance. However, if they are equipped with AVL technologies they can also provide travel time measurements on freeway links.

Data processing at BATOS will start with filtering of field data, followed by fusion of filtered data, and then estimation of parameters which may be useful for information dissemination. Data filtering includes checking validity and accuracy of the data collected from different sources. Reliability of a data collection source (i.e., probability of providing correct information) may be determined by analyzing the past history of the source. For example, the chance that the incident location, reported by a cellular phone caller, is within X miles from the actual incident location might be less than Y%. Also, past history can be analyzed by comparing the actual incident duration versus the predicted one among different sources.

Consistency of the incoming data can be checked by comparison with other reliable data sources. If the incoming data from a less reliable source becomes increasingly inconsistent, then it may be ignored. The filtered (refined) data from different sources will be fused to generate an integrated picture of the event (e.g., incident). Parameters which are useful for information dissemination can be derived from the filtered data, e.g., predictions of incident duration, capacity reduction, and consequently expected length of incident delay.

Information will be disseminated to individuals (through Changeable Message Signs, and pre-trip/enroute information systems), to the media such as commercial radio and television stations, and to public/private agencies such as CHP and FSP. The data will be disseminated systematically. In the case of individuals and the media, this requires developing procedures for proper implementation of dissemination strategies (user optimal or system optimal). Individuals may be given advice on travel choices as well as predictive information. The dissemination strategies will try to avoid adverse effects of information such as “aggregation,” i.e., causing congestion on alternate routes due to diversion of an unexpectedly large number of vehicles.

Raw and processed data will also be archived in BARTID for later use by practitioners, researchers, and private and public agencies. Practitioners can use the data for improving transportation system designs, planning, and operations. Researchers can use BARTID to establish patterns and to calibrate network planning and simulation models.

Measurement of Network Performance: Travel Times

Travel time measurements are important for estimating and predicting network performance; they can provide a dynamic measure of recurring and/or incident congestion, they are needed in assessing traffic management strategies, and they can be used in planning and evaluation of transportation projects. Travel time measurements can also be used in validation of off-line traffic simulation models, network models, and the Model 170 controller data.

An effective travel time measurement system should gather data continuously and automatically on important network links. Also, the system should be environmentally sound, should not require frequent maintenance, and should be economically feasible.

In addition to the loop detectors, travel times will be measured with probe vehicles. The probe vehicles will form part of the system needed for monitoring roadways and they will be particularly useful in gathering data on the city streets where loop detectors will not be installed. As mentioned earlier, probes can be AVI tagged vehicles, fleet vehicles such as transit buses, vanpools, and taxi cabs, ATIS equipped vehicles, and FSPs. To use these vehicles for travel time monitoring, "interrogators" will be installed on the main routes. The movement of probe vehicles will be monitored at the TOS.

Currently, there is no methodology for estimating the number of probe vehicles needed to provide the TOS with reliable link performance data (e.g., travel time). Furthermore, it is necessary to develop methods for interpreting and analyzing the data gathered from probes. A combination of research and field experiments can be used to assess the concept, design, and feasibility of large scale probing demonstration in the Bay Area.

A microscopic model developed by Sanwal and Walrand (1992) can be used to estimate and predict travel times on highway sections. Travel time predictions can be based on:

- Travel times experienced by vehicles which have traversed the section, and on

- The total number of vehicles occupying ♦♒♏ section.

The model will include probe vehicles and will be validated using real data. The analysis will provide:

- Design guidelines for a large scale Bay Area probing demonstration project. This includes methodologies for determining the proper location and frequency of probe vehicles in Bay Area corridors. This is also important in establishing a basis for cost comparisons and investment decisions among the different data collection sources (e.g., loops versus probes).
- Clean set of probe data (collected from field tests). These data can be used in model validation, project planning, and evaluation. For example, probe data may be used in validating dynamic traffic simulation models and traffic assignment algorithms.

Travel times can be verified through loop detector data which will be installed on freeways. Also, FSP vehicles will be equipped with map matching and automatic vehicle location systems. Therefore, the TOS will be able to track these vehicles as they move on freeway sections and obtain dynamic travel time measurements on the freeway sections and city street links.

Incentives may be needed to increase the possibility of participation in travel time monitoring. For example, incentives for taxi cab companies to participate in the experiment may be to expedite processing of their taxis at the airport terminals (e.g., loading and unloading passengers and luggage) which translates into faster service and a possible increase in profit. Another incentive is that dispatchers will know in real-time the locations of their taxis and they will be able to detect possible emergency malfunctions. Also, taxi cab drivers (as well as passengers) may feel safer and more secure if they know that the location of their vehicle is monitored by the dispatcher.

Prediction of Network Performance

Short-term prediction of network performance is needed both from a behavioral and systems perspective. Individuals want to know the conditions at any given point (or link) when they reach the point; moreover, with predictive information they will presumably make better and more informed judgements regarding their travel choices. Changes in behavior due to predictive information can translate into improvement in network performance. Two examples for predicting network performance are presented for illustrative purposes.

Prediction of Incident duration

The factors which influence incident duration include incident characteristics, environmental conditions, and operational factors. For example, incident duration may be longer if the incident involves injuries and fatalities, if the weather is adverse, or if the response team takes longer to reach the accident scene, and clear the incident. These factors can be used to predict incident duration as events occur. For example, a ***sequence*** of information acquisition in the BATOS (after the occurrence and detection of an accident) may be how long the response team and FSPs take to arrive at the scene, the extent of freeway damage, nature of the accident (the number of vehicles involved, whether it involves trucks/injuries), number of lanes blocked by the accident. The weather conditions are likely to be known at the beginning of-the accident. It is possible. to develop models which will predict incident duration based on when information becomes available. Specifically, statistical analysis can be used to predict how long an incident duration will be when the weather conditions and response time of the FSP becomes available. Then, if information about extent of freeway damage and nature of the accident becomes available, the models may update the clearance time estimate (by incorporating these variables in statistical models).

Short-Term Prediction of Travel Times

Procedures for estimation of current network parameters such as travel times and speeds based on loop detector data are developed, however, it is also desirable to predict travel conditions in the short-term (15 to 30 minutes). The short-term fluctuations in flow over a highway link may be caused by ***changes in:***

- Demand due to peak period or special events such as sports, festivals, etc.
- Maintenance and construction operations.
- Vehicle mix.
- Police activity.
- Incidents and response of various agencies to clear the incident.
- Environmental conditions such as weather.
- Control strategies such as ramp metering.

The accuracy of travel time predictions can be assessed through large scale FOTs involving use of vehicles as probes. Statistical estimators for travel time prediction can be developed and validated using field observations, e.g., through FSP field tests.

SUMMARY

The information collection and processing will require a central facility. The procedures for data collection, processing and dissemination will be based on analytical, simulation, and/or statistical models. For example, the testbed research will complement on-going and proposed field surveillance projects such as the Cornerstone Project by developing new methodologies (vehicles-as-probes) for collecting travel time information. In addition, models will be developed for predicting network performance.

CHAPTER 5

TECHNOLOGY ASSESSMENT

One of the challenges in designing the ATIS testbed is to develop a methodology which selects candidate technologies for field operational testing (FOT) and further evaluation. This is particularly important because the implementation of any experiment demands time and resources. Furthermore, it may not be practical to design a testbed which can accommodate all available ATIS technologies. In-depth assessment of the selected technologies for field testing will be conducted during the FOTs. The taxonomy discussed in Chapter 2 will be helpful in this regard. This chapter further discusses the technology assessment issues related to individuals' response to ATIS and its impacts on network performance.

TRAVELER RESPONSE TO ATIS TECHNOLOGIES

The technology suppliers (e.g., Siemens, Bosch and Motorola) offer, or propose to offer, ATIS technologies which have various attributes. For example, one attribute is whether the information given is static or dynamic. There is a need to know how travelers will respond to various technology attributes. Thus, the fundamental behavioral question is how will ATIS influence pre-trip and enroute decisions? Further, the FOTs will attempt to answer the following questions:

- Whether to "customize" information to account for the differences among individuals and contexts. That is, should drivers be allowed to select criteria for routes (e.g., minimum time or the most scenic), choose preferences (e.g., for route diversion and return to the original route), and select information displays (e.g., audio or visual)?

- Whether the design of information systems should be "flexible" enough to allow the learning of user preferences automatically and continuously.
- Whether to "package" information on transit, traffic, "yellow pages," and parking rather than disseminating it separately.

There is also a need to know the level of information detail needed to best support decision making. For example, in addition to travel time information, individuals may require information on exact location of incidents and expected length of delays.

Traveler decisions may be strongly influenced by the technology through which they receive the information, in addition to the content, format, type and attributes of information they receive, as well as attributes of the alternatives, individual and trip characteristics, environmental conditions and situational factors.

Before the commencement of **FOTs,** surveys will be used to assess traveler response. Individuals can assess the importance of various **ATIS** technology attributes by answering stated preference questions. The basis of surveys can be the taxonomy of **ATIS** technologies.

Various methods will be used to understand traveler response to **ATIS** in the field. For example, during the auto-related experiments, a combination of vehicle monitoring and longitudinal surveys can be used. The data collected from monitoring vehicle movements can provide rich behavioral insights because the observations will be relatively unobtrusive and free from reporting errors. These data along with service characteristics of the routes can be used to understand route and diversion decisions. The surveys of panel participants, conducted during the **FOTs,** can focus on reported preferences (past experiences) regarding the tested technologies. To answer behavioral and policy questions, the analysis will involve the use of multivariate techniques such as discrete choice modeling and structural equations analysis. Multivariate techniques are distinctly superior to the examination of variables independently as they compensate for inter-dependencies among exploratory variables.

HUMAN FACTORS

One of the key components in information dissemination is the interface between the traveler and the information system. Information can be disseminated either visually or audibly (or both visually and audibly). Further, visual and audio information can be presented in several ways, e.g., visual information can be presented in automobiles either through a heads-up display or through a Cathode Ray Tube (CRT) located in the dash board. Information may also be presented through text or map displays on Changeable Message Signs. There is a need to understand which methods of presentation are appropriate in particular contexts. A sizable body of literature on the design of Changeable Message Signs exists (Heathington et al. 1973; Dudek 1979; Dudek et al. 1986) and it can provide useful insights for designing out-of-vehicle (and in-vehicle) information displays.

In-vehicle information displays may affect safety, e.g., accidents may result from distractions caused by **ATIS** displays. In this regard, understanding the nature of driving tasks and how information displays may influence them will be useful. Driving tasks can be classified as "control" which include steering control and speed control, "guidance" such as car following and overtaking, and "navigation" or route selection (Allen et al. 1971). It is important to understand how various information displays, whether audio or visual, can influence the performance of these tasks (Allen et al. 1991).

Individuals' information processing capacity is limited and it may vary across people. Further, there may be differences across individuals in their ability to comprehend information. Therefore, it will be appropriate to investigate how complicated the information display can be for proper comprehension and absorption of information.

To study these and other aspects of human factors, laboratory-based simulation studies will be appropriate. The University of California at Davis is conducting human factors studies. The results of precursor studies and experience gained in other **ATIS** studies will guide the initial development of interfaces. During the field operational tests, more experience will be gained about how **ATIS** users perceive various information displays. This will result in the refinement of information interfaces.

TRANSPORTATION SYSTEM PERFORMANCE

The research before and during FOTs will investigate changes in system performance with various scenarios of ATIS technologies (e.g., technologies that provide dynamic qualitative information) and will address the following questions:

- Under what incident congestion conditions and/or recurring congestion conditions will ATIS be useful?
- How sensitive is system performance (with ATIS) to.network and incident parameters and to the fraction of vehicles equipped with ATIS?
- How do the changes in travel choices (due to ATIS) influence transportation system performance (especially under incident conditions)? Changes in travel choices can include: enroute diversion, increase in rideshare, and increase in transit ridership.
- What is the impact of various information dissemination strategies on system performance?
- What is the potential for diversion during peak/off-peak conditions in the Bay Area corridors?

The precursor studies will develop off-line simulation and dynamic traffic assignment models to answer the above questions for large scale networks. The models will consider explicitly information type, content, and format provided by ATIS technologies. However, major research efforts are needed for:

- Simulation of network travel conditions with and without ATIS.
- Dynamic assignment of vehicles equipped with ATIS and vehicles unequipped with ATIS.
- Modeling the impact of different information strategies on traveler behavior and consequently on system performance.

The off-line simulation models can be validated using data collected through the FOTs which will be conducted in the Bay Area corridors. Also, the FOTs will provide an opportunity for on-line simulation of network travel conditions, i.e., using real-time data available in the Bay Area TOC(s). This will provide a rich methodology for researchers and practitioners to select the appropriate traffic simulation models.

Strategies for Information Dissemination

The research as well as the FOTs will investigate impacts of various information dissemination strategies on traveler behavior and on system performance using the developed simulation and traffic assignment models. The strategies are divided into user optimal and system optimal strategies.

User Optimal Strategies

The following strategies will be considered:

Providing Descriptive Information. ATIS provides travelers with a description of traffic events such as incidents. This may support traveler choices such as mode, departure time, and route. No specific advice is given to travelers. Descriptive information may be qualitative or quantitative or both. An example of qualitative information is the message: "There is an accident on the Bay Bridge," while an example of the quantitative information is the message: "The accident will be cleared within one hour."

Providing Prescriptive Inform&on. ATIS gives instructions or advice for ATIS users such that they can individually optimize their choice of route, mode, and departure time. Prescriptive information can be qualitative, quantitative, or a mixture of both. An example of qualitative information is to advise travelers on usage of a certain route. An example of a mixture of qualitative and quantitative information is to advise travelers to use a certain route and justify the advice by giving the amount of time saved if the suggested route is followed.

In an attempt to demonstrate if and when system equilibrium can be achieved, the FOT management may adjust diversion rate to the alternate route(s); for example, in cases of low response to diversion instructions FOT, management may instruct more vehicles to divert for achieving network equilibrium.

System Optimal Strategies

Using developed simulation models, the research will explore and analyze impacts of system optimal strategies such as to:

- Minimize total travel time in the network
- Prevent diversion spillbacks and/or traffic backup to city streets.
- Minimize social cost of traffic diversion to city streets, e.g., pollution/environmental problems.

In addition, the effect of strategies which encourage time and mode shift will also be examined.

System optimal can be achieved through the dissemination of prescriptive information. However, system optimal advice may conflict with the traveler's own choice of route, mode, and departure time (e.g., some travelers may be instructed to use longer routes). Several methods can be used during the FOT to increase traveler compliance to system optimal advice. One is to constrain advice conditioned to the threshold of the traveler's tolerance. For example, length of diversion route may increase the traveler's trip time by a small amount that is not perceived by the traveler. However, if the diverted traveler is in front of a long queue, then large system savings can be achieved because of his/her diversion. Another method is to provide monetary incentives (e.g., toll discounts) for travelers equipped with ATIS to follow the system optimal advice.

SUMMARY

Assessment of information technologies will require understanding of traveler response to information (at the micro level) and impacts on system performance (at the macro level). The behavior of automobile drivers can be assessed through a combination of field monitoring and survey research. Further, to design interface(s) between the traveler and the information system, research on human factors will be conducted. The transportation system performance will be evaluated through off-line and on-line simulation. The simulation tools will be used to test system optimal and user optimal dissemination strategies.

CHAPTER 6

FIELD OPERATIONAL TESTS

This chapter describes example field operational tests which will be conducted in the Bay Area. This is not an exhaustive list of FOTs. They are initial thoughts on some of the experiments.

VEHICLES-AS-PROBES EXPERIMENTS

As discussed earlier, probe vehicles will be used for:

- Monitoring network performance, particularly measuring travel times on freeway and city street (or arterial) links. This will be done through the use of AVI/AVL technologies.
- Incident management, particularly for incident detection, verification, response, and clearance.

In addition, vehicles equipped with ATIS technologies will be used for diversion to a monitored alternate route under incident conditions to alleviate congestion on the incident route.

Also, “hybrid” experiments, combining two or more of the aforementioned FOTs, are desirable because they can enrich the results. For example, ATIS probe vehicles can be used for incident detection, verification, response, clearance, and diversion; FSP vehicles can be used for incident detection and link travel time measurements. A description of the diversion experiments follows.

Diversion of Vehicles Equipped with ATIS

These experiments are designed to measure system benefits of improved incident management through diversion of ATIS equipped vehicles to less congested (if any) alternate routes. It is expected that larger system savings can result from diversion under off-peak incident conditions (Al-Deek 1991). Diversion under peak conditions can also be investigated to test whether or not network equilibrium exists. There are two possibilities for conducting the experiment:

1) A simple road network composed of two bridges can be used. The selection of San Mateo and Dumbarton bridges for this experiment has been described in Chapter 3.
2) A network which consists of a freeway and an arterial can be used. A 14.5 mile segment on Route 101 between the Capitol Expressway and Route 237 in the San Jose area seems appropriate for the freeway-to-arterial diversion. The statewide SMART corridor study by JHK & Associates (1990) identified this freeway corridor as having the highest amount of total delay. A series of connected arterial segments in the corridor offer feasible alternatives to the freeway for the following reasons:

- The arterial segments have excess capacity.
- The City of San Jose is supportive of a SMART corridor idea (which reduces or eliminates conflicts because of diverting traffic to city streets).
- The City of San Jose is implementing a computer controlled traffic signal system which can potentially assist in monitoring traffic conditions on the arterial segments.

Diversion to alternate routes will likely reduce incident durations and queue lengths. The diversion may be achieved by providing incident information to ATIS equipped vehicles and/or to drivers through Changeable Message Signs. Conceptually, incident duration and queue lengths may be influenced by whether or not information about the incident is disseminated through the media, whether ATIS equipped vehicles are diverted, operational performance of the response system, incident characteristics (such as the number of vehicles involved in the incident and number of lanes blocked), existing traffic conditions (such as speeds, peak or off-peak), and environmental conditions (such as weather and pavement conditions).

The specific objectives are to:

- Determine the number of vehicles needed to produce desired system improvements.
- Observe improvements in incident duration and cumulative vehicle-hours of incident delay because of diversion to alternate routes.

To understand the effect of ATIS on changes in incident duration and queuing, a before-and-after study design can be used. Detailed data on ATIS performance, operational performance, incident characteristics, and existing traffic and environmental conditions will be needed. If enough vehicles can be diverted to the "alternate" bridge or route, then significant reductions in cumulative hours of delay may be observed in the field. Statistical analysis will be used to test this hypothesis.

The experimental design will account for confounding factors. For example, in addition to the ATIS equipped vehicles and Changeable Message Signs, information on the incidents may also be disseminated through the media, e.g., radio traffic reports. Changes in the quality of such reporting during the experiment can confound the results because individuals may start changing their travel decisions in response to improvements in incident reporting. Therefore, changes in information disseminated through the media will be monitored closely. It will also be necessary to account for seasonal variations in incident-induced congestion. For example, severe accidents may be more likely to occur during certain times of the year--e.g., during the rainy season.

Statistical techniques will be used to analyze existing "before" data. Models which relate incident duration to operational performance of the response system, incident characteristics, existing traffic conditions, and environmental conditions will be developed. Eventually, the models will compare the before and after data by using separate and pooled models to understand the changes.

BEHAVIORAL EXPERIMENTS RELATED TO TRANSIT

A service which provides static and dynamic transit information may increase transit ridership. However, it is not clear what information may be useful for increasing transit use. This FOT will assess requirements of a transit information service which provides historic as well as real-time information through a central system. The system will collect and process information regarding (previously) scheduled and current operations of the transit system and determine the best course of action (e.g., transit routes) for customers. The communication medium (to potential transit users) can be a personal computer at home or in office, telephone, facsimile, or teletext/videotext terminal. The main research objective is to evaluate the potential for increasing transit use through an advanced transit information service.

The following information can be provided to users:

Static-Qualitative Information. Examples of staticqualitative information are possible bus routes.

Static-Quantitative Information. Examples of staticquantitative information are normal bus and train schedules.

Dynamic-Qualitative Informution. The transit information system may inform individuals of delays due to emergencies.

Dynamic-Quantitative Information. The service may give information on the expected length of delays, and current travel times on intended routes.

To understand the effect of transit information, a before-and-after control group design can be used. The control group will help distinguish the effect of transit information (by permitting comparison across individuals with and without transit information). A before study can identify individuals' needs for various types of transit information; such knowledge can be used to refine the design of the transit information system.

The method for assessing behavioral impacts of the transit information service will be survey research and interviews. Specifically, the need for static and dynamic information will be evaluated through travel surveys. They will also assess behavioral changes, i.e., possible shifts from the automobile to transit due to the information service. Revealed and stated preferences can be used in the surveys. Discrete choice analysis can be used to quantify changes in probability of using transit. The analysis will help in designing transit information services of the future.

MULTIMODAL EXPERIMENTS

The concept of a multimodal integrated transit systems (MITS) can be tested for its feasibility in the Bay Area. MITS is the integration of Smart Transit and Smart Traveler systems with a system providing real-time travel and ridesharing information to vehicle operators and transit users. The Smart Transit concept is an integration of fixed-route transit, dial-a-ride minibus, and paratransit services. An operational test of the Smart Transit concept is currently underway in the Tri-County area in Oregon.

The Smart Traveler concept is the making of real-time traffic and rideshare information available to vehicle operators and customers. Customers will use the information for pre-trip planning and mode choice while operators will use the information for dispatching services. The concept of Smart Traveler will be tested in Houston, Texas, and Bellevue, Washington.

The Bay Area experiment differs from other experiments in the integration aspects of the Smart Transit and Smart Traveler systems. To determine the feasibility of the MITS, the concept needs to be developed, tested, and evaluated in selected regions. With many mode choice options available, the Bay Area is well suited for demonstrating the feasibility of a multimodal integrated transit system. The suggested corridor for this experiment is the congested I-80 corridor which includes the San Francisco/Oakland Bay Bridge.

The FOT will integrate real-time schedule information for all modes: bus, BART, and ferry services as well as car- and van-pools. The schedule information will be transmitted to a centralized database where the real-time schedule information can be disseminated to transit riders via telephone, fax, home computer and variable message signs at transit stations. The goal of this experiment is to test the viability of an integrated transit system to encourage rideshare and transit use.

CONGESTION PRICING EXPERIMENT

For many years, road pricing has been thought of as a potentially viable option in managing traffic congestion, yet the concept has not been fully tested in a real world situation. There is a need to study the feasibility of road pricing for severely congested areas. The San Francisco/Oakland Bay Bridge is the most congested segment of the I-80 corridor. Congestion pricing is one method of influencing bridge users to change their travel habits. The proposed experiment is a test of congestion pricing by increasing the bridge toll during peak-hours. Potential benefits include reduced congestion due to mode shift, time of day shift, and deferred trips.

The key issue in congestion pricing is the form of user charge. With the AVI technology it is possible to charge users according to the actual usage of transportation facilities. As demand increases, there will be a greater pressure to apply the "user pays approach" to those segments of corridors which do not have many options to manage traffic.

Traffic congestion costs on the Bay Bridge are extremely high and congestion is caused to a large degree by vehicles driven alone. Yet those vehicles traveling on the bridge during peak and off-peak hours are charged the same toll. The present method of charging tolls seems inequitable because off-peak users are paying for the external costs generated by peak-hour users. In this experimental study we will address two issues important to the Bay Area: (1) community acceptance of an increase in toll charge and (2) public policies which will discourage the use of single occupant vehicles, especially during peak periods.

CHAPTER 7

MANAGEMENT PLAN

The purpose of this management plan is to create an organizational structure that insures the timely, efficient and reliable installation of the testbed infrastructure, and to insure adherence to scientific objectives in the conduct of research experiments. To this end, the plan exploits the unique experience and knowledge of both the private and public sectors, while giving primary managerial responsibility to the public sector.

STRUCTURE AND RESPONSIBILITIES OF MANAGEMENT

As illustrated in Figure 7.1, a guiding principle of the testbed organization is that testbed policy will be the responsibility of a five member management board comprising representatives from key public agencies. Execution of these policies will be the responsibility of two managers: the project manager will have primary responsibility for installation and operation of the testbed. The PATH testbed manager will be responsible for coordinating research. These responsibilities are described in the following sections.

Testbed Management Board

The Testbed Management Board (TMB) is the policy setting body for all testbed activities. The TMB is responsible for reviewing and approving all contracts for the installation of testbed infrastructure. The TMB is also responsible for reviewing and approving procedures for the conduct of tests, setting access restrictions to databases and for evaluation and deployment of ATIS technologies. Finally, the TMB is the ultimate authority for approval of research experiments.

Membership. Five members representing key public agencies, will be appointed by:

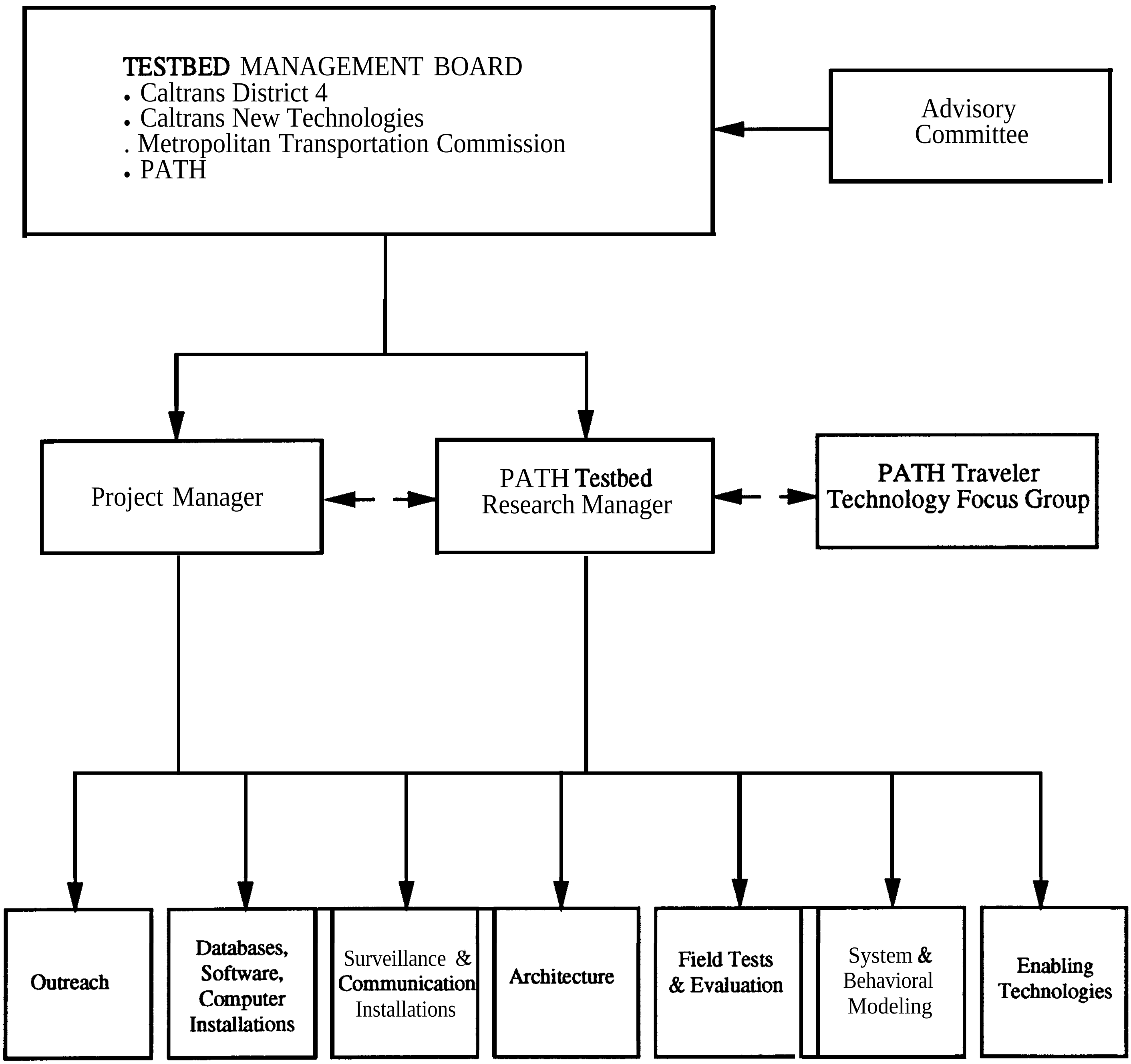


Figure 7.1 Bay Area Testbed Management.

(1) Director of Caltrans District 4

(2) Director of Caltrans New Technologies

(3) Director of the Metropolitan Transportation Commission

(4) Director of PATH.

The public sector appointees will remain on the committee until resignation or removal by the appointing agency.

Advisory Board

The TMB will be empowered to form (or disband) an advisory board and advisory committees. The purpose of these bodies will be to capture a wide range of knowledge from the broader ATIS community, thus enabling more effective deployment of ATIS technology. Members may include (but are not limited to) representatives from local municipalities, transit agencies, consultants and other private sector representatives. The advisory board will have no direct authority for setting testbed policy and procedures or for reviewing projects.

Project Manager

Under the policy direction of the TMB, the Project Manager is responsible for directing technology installations and operations, including the deployment of surveillance, computation, communication and database systems. The Manager will also be the primary contact to private sector firms that wish to access the database.

PATH Testbed Manager

Under the policy direction of the TMB, the PATH Testbed Manager is responsible for coordinating all research activities in the testbed, to include field operational tests and evaluations, system modeling and surveys.

The PATH Testbed Manager will be responsible for drawing on researchers affiliated with

PATH from throughout the-state. These will primarily come from those affiliated with PATH's "Traveler Technology" focus group, but may also include researchers working on Operations, Systems and Policy. More generally, the PATH Manager will be responsible for insuring that the most up-to-date technology is transferred from PATH research projects to the Testbed.

RULES AND PROCEDURES

To insure that research projects are properly coordinated with each other and with deployments, the TMB will be responsible for issuing rules and procedures in the following areas.

Access Protocol

Although a principal of the Testbed design will be open access, there will still be a need to determine which technologies are most promising for improving travel conditions. With this need in mind, private sector information providers should be required to file a protocol statement prior to accessing the database. The statement will request a detailed description of the technology and how the information will be used, along with a marketing plan and prototype device. In addition, providers will be required to file a quarterly statement specifying the number of users and any deviations from the initial plan.

The Project Manager will have authority to approve protocol statements, and will guarantee a decision within 14 days of application. Exemptions can be requested, but must be approved by the TMB.

The Project Manager and PATH Manager will be jointly responsible for developing the access protocol statement, which must be approved by the TMB.

Research Protocol

Consistent with the standards outlined in Chapter 3, the Project Manager and the PATH Manager will develop the research protocol statement, subject to approval by the TMB. Prior to conducting any experiment in the TMB, the investigator must file the statement with the PATH

Manager. The PATH Manager will then conduct an administrative review of the experiment, confer with the Project Manager and recommend approval, denial or changes. The PATH Manager will present his or her findings to the TMB for endorsement. At its discretion, the TMB may also request a presentation by the investigator.

Data Verification

The Caltrans and PATH managers will be jointly responsible for formulating testing procedures and reference standards for data integrity. The procedures must be satisfied before any party is allowed to deposit data into the running data base.

PROJECT TIMING

The **ATIS Testbed** will be developed in parallel with ongoing activities in Caltrans District 4's Cornerstone program. Specifically, installation of loop detectors and communications systems will be governed by the Cornerstone schedule.

The initial phases of the program should center on the core regions (I-80 and Santa Clara County) specified in earlier chapters. Subsequent phases should expand the coverage to other areas and add a capability for mobile communication to travelers en route. This section outlines those activities that pertain to the research aspects of the **ATIS Testbed.**

Activities in the initial months (up to 3) will include:

(1) Manager selections and appointments to TMB.

(2) Specifications for systems architecture.

(3) Issuance of **RFP** for database and computer installations.

(4) Research on enabling technologies.

Activities in the next few months will include:

(1) Review of proposals and selection for database/computer installations.

(2) Issuance of access, research and data protocols.

(3) Research on enabling technologies.

(4) Selection of participants in longitudinal survey.

Activities in the following year will include:

(1) Formulation of systems architecture for communication to vehicles. Issuance of RFP and selection of contractor.

(2) Creation of probe vehicles fleet, installation of monitoring equipment, and testing/verification of probe algorithms.

(3) Initial longitudinal survey.

(4) Continued research on enabling technologies.

By the end of the second year, the testbed will become operational within the core regions. Subsequent activities will include:

(1) Initial field operational tests of technologies.

(2) Second round of longitudinal survey.

(3) Research on behavioral response to new technologies.

Efforts from this point on will center on:

(1) Increasing service area coverage.

(2) Continued field operational tests of dissemination technologies.

(3) Continued longitudinal survey and behavioral research.

(4) Integration of new technologies into the testbed infrastructure.

REFERENCES

ADVANCE, ***Scope, Feasibility and Cost of a Dynamic Route Guidance System Demonstration,*** Final report submitted to the Illinois DOT by Illinois Universities Transportation Research Consortium, Chicago, Illinois, 1990.

Al-Deek H., M. Martello, and A. May, " Potential Benefits of In-Vehicle Information ***Systems (IVIS)," Proceedings*** of ***1st Vehicle Navigation and Information System Conference (VNIS '89),*** sponsored by IEEE, Toronto, Canada, 1989.

Al-Deek H., ***The Role of Advanced Traveler Information Systems in Incident Management,*** PhD Dissertation, Department of Civil Engineering, Institute of Transportation Studies, University of California at Berkeley, UCB-ITS-DS-91-5, 1991.

Al-Deek H., ***A. Khattak,*** and ***A. Kanafani, Framework for Analyzing Transportation Networks with Advanced Traveler Information Systems,*** PATH Research Proposal, Institute of Transportation Studies, University of California, Berkeley, 1992.

Allen T., H. Lunenfeld, and ***G.*** Alexander, "Driver Information Needs," ***Highway Research Record*** 366, Highway Research Board, Washington, D.C, 1971, pp. 102-l 15.

Allen R, D. Ziedman, T. Rosenthal, A. Stein, J. Torres, and A. Halati, "Laboratory Assessment of Driver Route Diversion in Response to In-Vehicle Navigation and Motorist Information Systems" Preprint # 910701, ***70th Annual Meeting of Transportation Research Board,*** Washington, D.C, 1991.

Bay Area Monitor, ***League of Women Voters of the Bay Area,*** November and December, 1991.

Bettman J., ***An Information Processing Theory of Consumer Choice.*** Addison-Wesley Publishing Company, Reading, Massachusetts, 1979.

Bonsall P., "Using an Interactive Route-Choice Simulator to Investigate Drivers' Compliance with Route Guidance Advice," Proceedings of ***6th International Conference on Travel Behavior,*** International Association for Travel Behavior, Quebec, Canada, 199 1.

Dudek C., G. Weaver, D. Hatcher, and S. Richards, "Field Evaluation of Messages for Real-Time Diversion of Freeway Traffic for ***Special*** Events," ***Transportation Research Record,*** 682, Washington D.C., 1978.

Dudek C., "Human Factors Considerations for In-Vehicle Route Guidance," ***Transportation Research Record,*** 737, Transportation Research Board, Washington D.C., 1979, pp. 104-107.

Dudek C., R. Huchingson and R. Bracken, "Studies of Highway Advisory Radio Messages for Route Diversion," Presented at ***Transportation Research Board,*** Washington, D.C., 1983.

Dudek C., and R. Huchingson, ***Manual on Real-Time Motorist Information Displays,*** Federal Highway Administration, FHWA-IP-86-16, US DOT, Washington D.C., 1986.

Golledge R. and R. Stimson, ***Analytical Behavioral Geography,*** Croom Helm, New York, New York, 1987.

Heathington K., R **Worrall,** and G. Hoff, "An Analysis of Driver Preferences for Alternative Visual **Information** Displays," ***Highway Research Record 303,*** Highway Research Board, Washington, **D.C,** 1973, pp. 1-15.

Jeffrey D., **K. Russam,** and D. Robertson, "Electronic Route Guidance by Autoguide: The Research Background," ***Traffic Engineering + Control, 28*** (1 **1), 1987a,** pp. 525-529.

Jeffrey D., "Route Guidance and In-Vehicle Information ***Systems," Information Technology Applications in Transport, VNU*** science Press BV, Utrecht, Netherlands, 1987b.

JHK **&** Associates, ***Smart Corridor Statewide Study,*** Final Report, Prepared for the State of California, Department of Transportation, June, 1990.

Kanafani ***A., Toward a Technology Assessment of Highway Navigation and Route Guidance,*** PATH Working Paper UCB-ITS-PWP-87-6, Institute of Transportation Studies, University of California, Berkeley, California, 1987.

Kanafani A., and H. Al-Deek, "A Simple Model for Route Guidance **Benefits,"*****Transportation Research*** B, Vo125 **(3),** 1991.

Khattak ***A., Driver Response to Unexpected Travel Conditions: Effect of Information and Other Factors,*** **PhD** Dissertation, Department of Civil Engineering, Northwestern University, Evanston, Illinois, 1991.

Kitamura R. and P. Jovanis, ***ATIS Impact on Travel Demand,*** PATH Research Proposal, Institute of Transportation Studies, University of California, Davis, 1992.

Kobayashi F., "Feasibility tudy of Route Guidance," ***Transportation Research Record 737,*** Transportation Research Board, Washington, D.C., 1979,107-l 12.

Koppelman F., and E. Pas, "Travel-Choice Behavior: Models of Perceptions, Feelings, Preference, and Choice," ***Transportation Research Record 765,*** Transportation Research Board, Washington, D.C., 1980, pp. 26-33.

Mahmassani H., and G.-L. Chang, "Dynamic Aspects of Departure Time Choice Behavior in a Commuting System," ***Trunsportution Research Record*** 1037, Transportation Research Board, Washington, D.C., 1985, pp. 88-101.

MTC, Bay Area Travel Forecasts for Years 1987, 1997 and 2010: Auto Ownership, Trip Generation and Trip Distribution, Technical Summary, Metropolitan Transportation Commission, March 1990.

MTC, Bay Area Street and Road Maintenance Needs, Summary Report, Metropolitan Transportation Commission, March 1982.

Proceedings of Second Vehicle Navigation and Information Systems **(VNIS)** Conference, **IEEE,** SAE, Dearborn, Michigan, 1992.

Sanwal K., and J. **Walrand,** ***Delay Prediction Using Vehicle Following Model,*** PATH Research Report, Institute of Transportation Studies, University of California at Berkeley, 1992 (in-preparation).

Simon H., ***Models of Thought,*** Yale University Press, New Haven, 1979.

APPENDIX

LEGEND

- PS&E
- Construction
- Integration
- → Operational

FIGURE 1

"PRE CORNERSTONE "
DAY AREA TRAFFIC OPERATIONS SYSTEM (TOS)
IMPLEMENTATION SCHEDULE
(Tentative)

DRAFT
1/29/92 JJS

	EA	FUND.	TOS Miles	Rnmps
. SFOBB TMS UPPER DECK		12/88 TBF	7.2	ML 114 Lanes
. TOS SEGMENT 1 (OAKLAND - SAN FRANCISCO)	150024	TBF	23.0	—
. METERING PORTION OF SCL 101 (SB) P.M. 40.0 /52.2	132451	88STIP	12.2	24
, Interim Traffic Operations Center (TOC) - Vallejo CHP	—	—		
, CENTRALIZE EXISTING RAMP METERMG ON ROUTE 101 IN SAN JOSE	126834	MINOR A	12.2'	12
. ROUTES 680/24 TMP	VAR.	STIP	9.0	—
. CENTRALIZE REMAINING METERMG IN SAN JOSE	150204	90/91TSM	14.9	26
a. METERING PORTION OF SCI 101 (NB) P.M. 27.0/30.2	is0224	90/91TSM	3.2	38
h. METERMG PORTION OF SCL - 101 (SB) P.M. 28.6/33.0	150234	90/91TSM	4.4	
c. METERING PORTION OF SCL - 280 P.M. 7.0/10.8	150214	90/91TSM	3.8	
. ER CMSs (2) /TRAFFIC MONIT. STAT. ALA - 880, SOL - 80	191664 150901	ER FUNDS MINOR A	1.0	
). CC/ALA 80 TMP	VAR.	STIP	13.0	
l.SFOBB TMS LOWER DECK, SF / ALA-80, P.M. 4.0 / 8.8 ; 0.1 / 2.5	030811	TBF	6.3	
2. METERING/TOS - PORTION OF ALA 880 (NB/SB) P.M. 13.7 / 20.7	150051	91/92TSM	9.1	18
3. METERING - PORTION OF SCL85 (NB/SB) P.M. 0.0 / 18.9	485011	91/92TSM	18.9	3[illegible]
4. METERING - PORTION OF SCL87 (NB/SB) P.M. 0.0 /5.7	150241	91/92TSM	5.7	11

* APPROXIMATELY 120 CENTERLINE MILES

LEGEND

- PR — Project Report
- PS&E
- Construction
- Integration
- → Operational

FIGURE 2 - S/COSTS

"POST CORNERSTONE"

BAY AREA TRAFFIC OPERATIONS SYSTEM (TOS) IMPLEMENTATION SCHEDULE

(Tentative)

DRAFT
3/12/92 JJS

CORNERSTONE PROJECT-Beg.3/91	R.A.	FUNDING	$M	1992 – 1998	Centerline Miles	
1.(A) TOC	50010 (A)	92/93 TBF	$2.5		INCL.	45.0
1.(B) TOS/METERING ALA-880, P.M.7.1/34.5	50060 (B)	93/94 TSM	$22	PR; FED 10/93; 3/94	45.0	
2. TOS, SCL-17,85,87,101,237,280,680,880, P.M. -VAR.	150260	93/94 TSM		PR	TBD	
3. TOS W-80, P.M.5.1/8.9 (STIP TSM PROJ)	)RY701	93/94 STP	$1.5	PR; 2/93; 9/93	NA	
4. SCL - 17, 101, 280, 680, 880, P.M. VAR. CMS (6), MONIT. STATION (6)	150250	)2/93 TSM	$1.2	7/92 PR; 3/93	NA	
5. MRN - 101 P.M. 7.4 / 203 CMS (4), CCTV ( ), HAR ( ), MONIT. STAT. ( )	150600	)2/93 TSM	$1.8	PR	12.8	
6. CC.24 P.M. 0.0 /7.8 CMS (1), CCTV ( ), HAR ( ), MONIT. STAT. ( )	150720	92193 TSM	$3.0	PR	7.8	46.7
7. SM - 101 P.M. 0.0 / 14.3 CMS (2), CCTV ( ), HAR ( ), MONIT. STAT. ( )	150410	)2/93 TSM	$5.0	PR	26.1	
8. SM - 101 P.M. 143 / 26.1 CMS (4), CCTV ( ), HAR ( ), MONIT. STAT. ( )	150420	92/93 TSM	$4.2	PR		
9. DUMBARTON BRIDGE * SM /ALA - 84 P.M. 25.7 / 30.15 ; 0 00 / 6.0	150430	93/94 TBF	$5.3	2/93 PR; 9/93	11.4	
10. SAN MATE0 BRIDGE * SM /ALA - 92 P.M. 12.14 / 18.8 ; 0.0 /6.39	150400	93/94 TBF	$10.8	PR	13.1	
11. CARQUINEZ BRIDGE * CC / SOL. 80 P.M. 10.06 / 14.14 ; 0.0 / 4.43	150700	93/94 TBF	$3.6	PR	8.5	41.3
12. BAY BRIDGE • ALA - 80 P.M. 0.00 / 3.21	150040	93/94 TBF	$2.4	PR	INCL.	
13. BAY BRIDGE • SF - 80 P.M. 3.95 / 8.85	150500	94/95 TBF	$1.0	8/93 PR; 8/94	INCL.	
14. BENICIA / MARTINEZ BRIDGE * CC / SOL- 680 P.M. 21.19 / 25.46 ; 10.00 / 13.13 SOL - 780 P.M. 0.68 / 1.52	150710	95/96 TBF	$5.0	2/95 PR; 1/96	8.3	

- CMS, &TV, HAR, MONITORING STATIONS, METERING